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MINISTRY OF EDUCATION

2023-2024

Inspire Science

**UAE Edition
Grade 6 • Unit 3
Student Edition**

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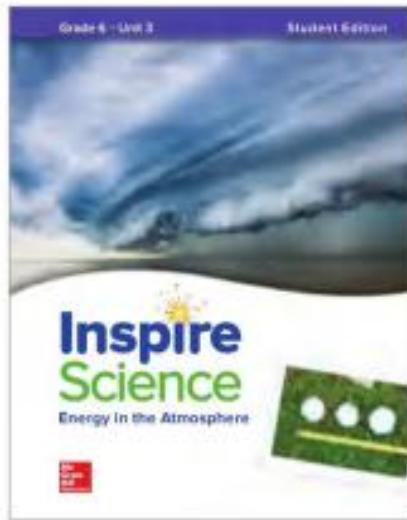
Grade 6 • Unit 3



Inspire Science

Energy in the Atmosphere

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Hill



Phenomenon: Why did these clouds form?

A storm front is a boundary separating two large masses of air. The two air masses typically differ in temperature, moisture content, and air pressure.

fun fact

The largest hailstone ever measured in the United States was 20 cm in diameter and 47.3 cm in circumference, weighing in at 0.88 kg!

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STEM

McGraw-Hill is committed to providing instructional materials in Science, Technology, Engineering, and Mathematics (STEM) that give all students a solid foundation, one that prepares them for college and careers in the 21st century.

Welcome to



Inspire Science

Explore Our Phenomenal World

Learning begins with curiosity. Inspire Science is designed to spark your interest and empower you to ask more questions, think more critically, and generate innovative ideas.

Start exploring now!



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SpongeLab Interactives is a learning technology company that inspires learning and engagement by creating gamified environments that encourage students to interact with digital learning experiences. Students participate in inquiry activities and problem-solving to explore a variety of topics through the use of games, interactives, and video while teachers take advantage of formative, summative, or performance-based assessment information that is gathered through the learning management system.



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The PhET Interactive Simulations project at the University of Colorado Boulder provides teachers and students with interactive science and math simulations. Based on extensive education research, PhET simulations engage students through an intuitive, game-like environment where students learn through exploration and discovery.



Measured Progress, a not-for-profit organization, is a pioneer in authentic, standards-based assessments. Included with New York Inspire Science is **Measured Progress STEM Gauge®** assessment content which enables teacher to monitor progress toward learning NGSS.

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Energy and Matter



ENCOUNTER THE PHENOMENON

What makes popcorn kernels pop?



 **GO ONLINE**

Watch the video *Popcorn Popping* to see this phenomenon in action.

Communicate Think about popcorn popping. Record your ideas for how you think this happens below. Discuss your ideas with three different partners. Revise or update your ideas, if necessary, after the discussions with your classmates.



STEM Module Project Launch

Engineering Challenge

Lesson 1

Particles in Motion



Lesson 2

States of Matter



Lesson 3

Thermal Energy Transfers



Lesson 4

Thermal Energy Conductivity



Cookin' with the Sun

You work at an engineering design company that develops alternative cooking methods. Your clients are a group of researchers preparing for a data collection trip where they will be in the field for an extended amount of time. For the last few years, their data collection site has been under drought conditions and no open flames are allowed. They have made a request for a device that will enable them to cook without using open flames.

Your goal is to design, construct, and test a device that is capable of heating a pot of water. You will present your device along with your constructed argument about the device's effectiveness to the clients.



Start Thinking About It

In the photo above, there are different sources of energy. Energy can be transferred in various ways and between objects. Explain which sources could be used to heat food.



STEM Module Project

Planning and Completing the Engineering Challenge How will you meet this goal? The concepts you will learn throughout this module will help you plan and complete the Engineering Challenge. Just follow the prompts at the end of each lesson!

LESSON 1 LAUNCH

Fruit Pops



Lina and Vera purchased fruit pops at the grocery store. The drive home was hot and the fruit pops turned slushy. After a few hours in the freezer, the fruit pops were solid again and ready to eat. What is the relationship between temperature and particle motion?

- A. Decreased temperature means particles have greater motion.
- B. Decreased temperature stops particle motion.
- C. Increased temperature means particles have greater motion.
- D. Increased temperature means particles have less motion.
- E. Temperature does not affect particle motion.

Circle the statement you most agree with. Explain why you agree with that statement.

You will revisit your response to the Science Probe at the end of the lesson.

Particles in Motion



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ENCOUNTER THE PHENOMENON

Why do some materials feel colder than others?

At the same time, pick up and hold a wood block in your left hand and a metal block in your right hand. Record your observations in the space below.



GO ONLINE

Watch the animation *You'll Never Be a Thermometer* to see this phenomenon in action.

EXPLAIN THE PHENOMENON

You climb out of the lake onto the wooden dock. You place a hand on the metal rail and a hand on the wood. One of the materials feels colder than the other. Why do you think this happened? Use your observations of the materials to make a claim about why some materials feel colder than others and how you can measure the hotness/coldness of the material.

CLAIM

Some materials feel colder than others because...

COLLECT EVIDENCE

as you work through the lesson.
Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain the energy of the two blocks?

B. What evidence have you discovered to explain how the temperature of the blocks can be measured?

MORE EVIDENCE

C. What evidence have you discovered to explain how models of the particles in the wood and metal blocks show why one felt colder than the other?

D. What evidence have you discovered to explain how the masses of the wood and metal blocks affect why one felt colder than the other?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Some materials feel colder than others because...

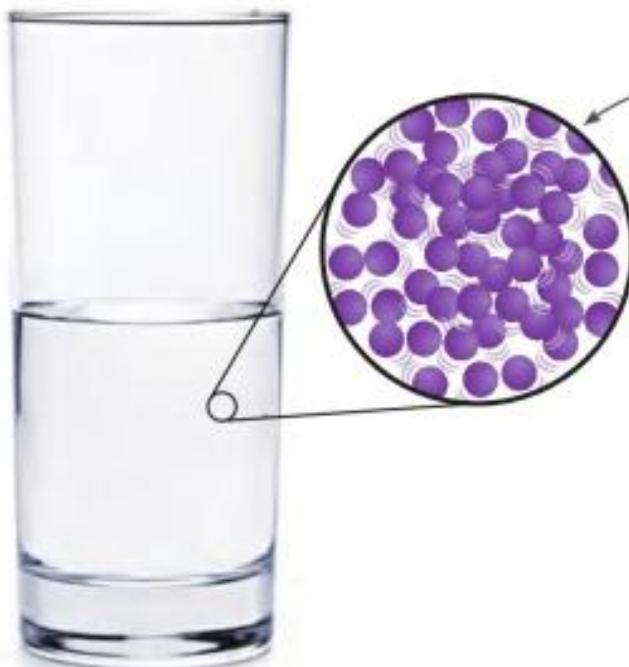
Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

How do particles move?

A particle is a small unit of matter. Every solid, liquid, and gas is made of particles including the metal and wood blocks from the previous activity. Do you think these particles move when an object is still? Let's find out!



What are these doing?

Want more information?

Go online to read more about the factors that affect particle motion.

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

LAB Wait For It

Safety



Materials

food coloring
beaker

room temperature water
stopwatch

Procedure

1. Read and complete a lab safety form.
2. Fill the beaker 3/4 of the way full with room temperature water. Set the beaker on a still surface. Wait until the water in the beaker has stopped moving. Record your observations in the table on the next page.
3. Carefully add two drops of food coloring to the beaker. Try not to disturb the water. Record your observations after 30 seconds, 1 minute, and 5 minutes in the table on the next page.
4. Follow your teacher's instructions for proper cleanup.

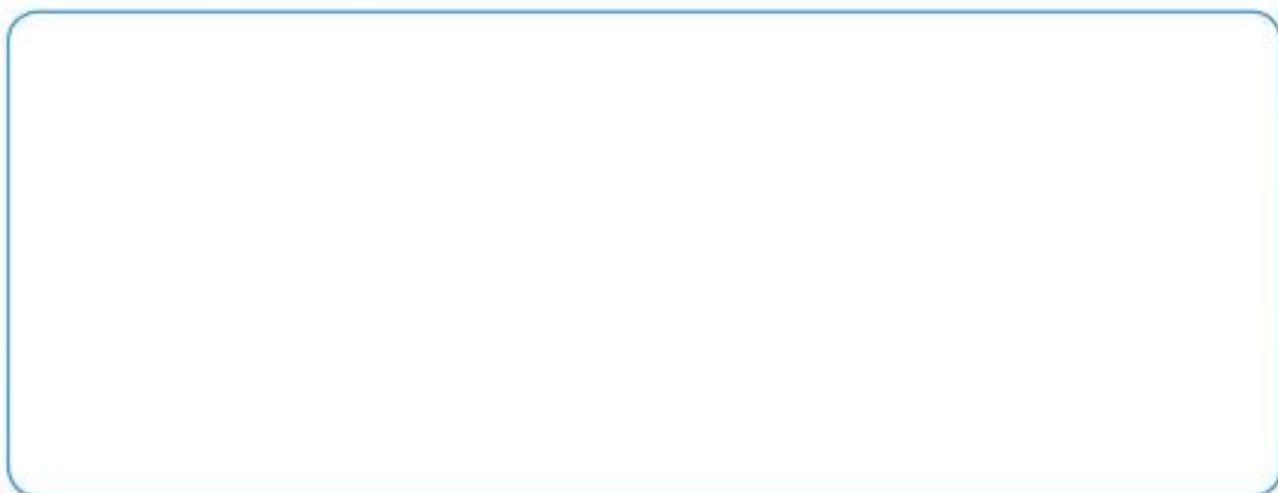


Data and Observations

Time	Before Adding Food Coloring	30 sec After Adding Food Coloring	1 min After Adding Food Coloring	5 min After Adding Food Coloring
Observations				

Analyze and Conclude

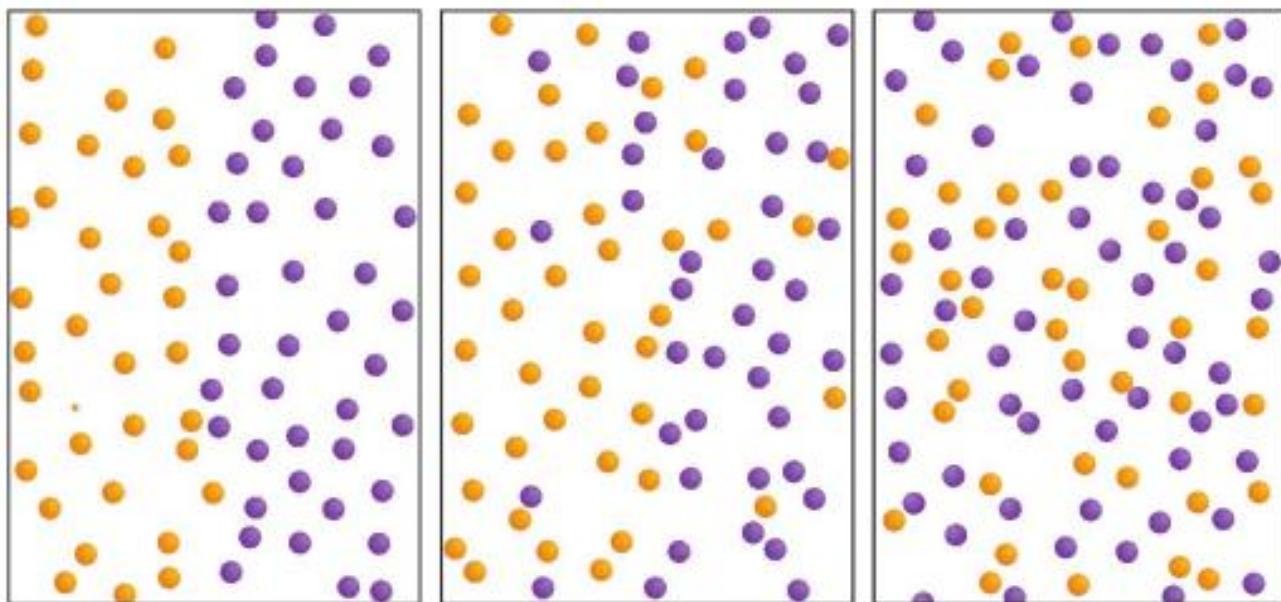
5. Sketch a model of what you think happened with the particles of water and food coloring based on your observations.



6. What claim can you make about the motion of the water particles? Use reasoning to explain how the evidence supports your claim.

Movement and Collisions In the Lab *Wait For It*, the food coloring moved when the water in the beaker appeared to be completely still. How did this happen? Water particles, like the particles in all liquids, constantly bump and flow past each other in **random motion**—movement in all directions and at different speeds. The movement and collisions of the water particles push the food coloring particles around, causing the coloring to spread out, or diffuse. **Diffusion** is the movement of particles from an area of higher concentration to an area of lower concentration. Diffusion does not happen instantly. Particles diffuse until the concentration is the same throughout the container. When the concentration of food coloring is the same throughout the container, the liquid is one color.

Take a look at the figure below. Notice that as you move from left to right, the particles become more diffuse.



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What determines how much energy particles have?

You know that a rolling ball has energy because it is moving. Particles also move, so they also must have energy. Remember, energy is the ability to cause change. Is there a relationship between how fast a particle moves and the amount of energy it has? Let's investigate!



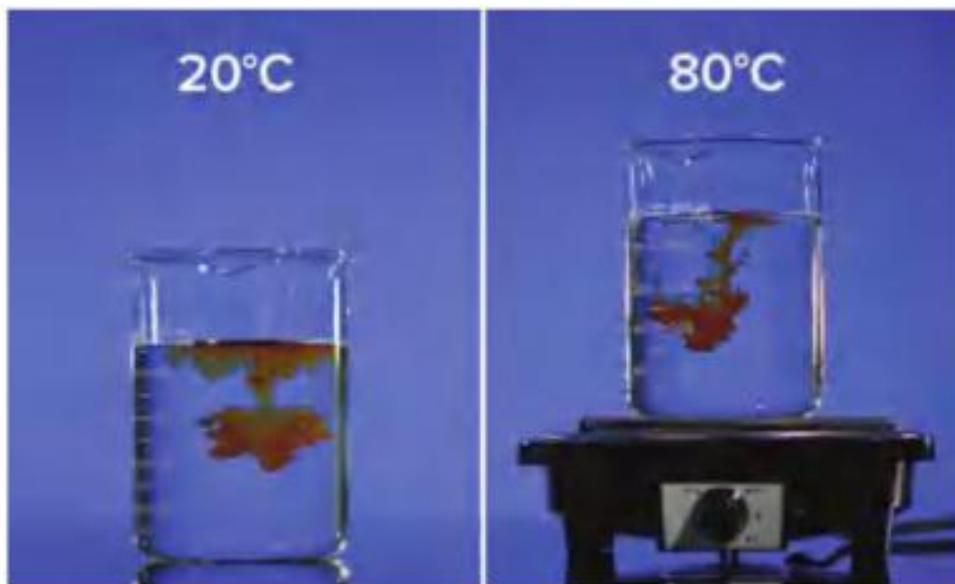
INVESTIGATION

Ready, Set, Collide

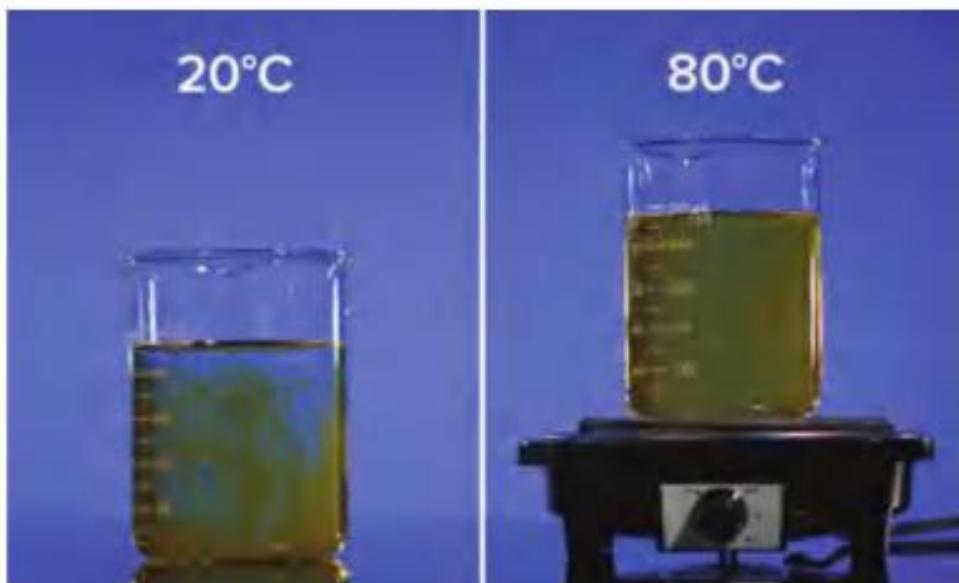
 **GO ONLINE** Watch the video *Dye Race* to investigate how adding energy affects particle movement. Record your observations below.



Use your observations from the video to draw conclusions about the figure below. What can you conclude about how adding energy to the liquid on the right will affect the speed of the particles?



Movement and Energy Scientists use diffusion to observe how fast the particles of a substance are moving. The faster the substance diffuses, the faster the particles are moving. In the figure below, energy was added from the hot plate to the water and dye particles on the right. This added energy increased the motion energy, also called **kinetic energy**, of the particles. As the kinetic energy of the particles increased, the speed of the particles increased. The faster particles move, the more kinetic energy they have.

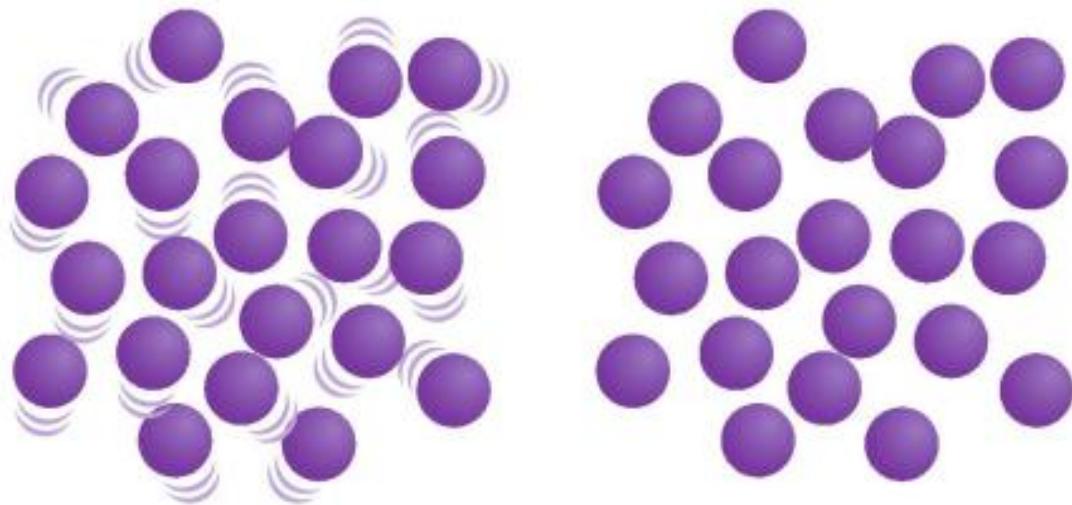


How to Model Movement Motion lines are used to model particle movement in a still image. Since particles travel at different speeds, they need to be represented by different numbers of motion lines. The more motion lines, the faster the particle is moving.



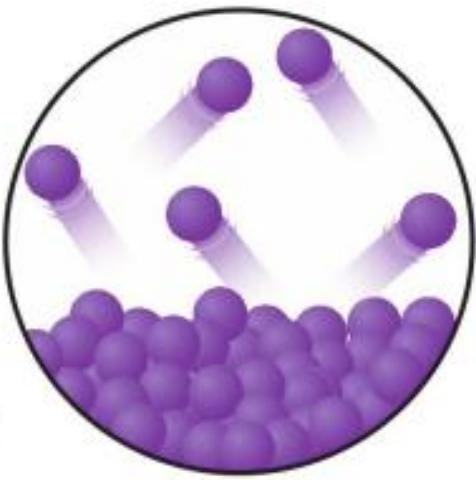
THREE-DIMENSIONAL THINKING

Add motion lines to the liquid particles **model** on the right to show they are moving faster than the liquid particles on the left. Circle the model that has more kinetic **energy**.



Read a Scientific Text

HISTORY Connection The earliest modern accounts of **thermodynamics**—the study of heat—can be traced back to the late 1700s through the early 1800s. One of the contributions to thermodynamics was by James Prescott Joule, an English physicist. His ideas on the particle motion of matter were often ridiculed by his peers, but they have continued to withstand the test of time. His contributions to science are recognized by naming the unit for energy the joule (J). The passage below is an excerpt from a lecture Joule gave in 1847.



CLOSE READING

PRIMARY SOURCE

Inspect

Read the passage from *On Matter, Living Force, and Heat*.

Find Evidence

Reread the paragraph. Underline the evidence Joule gives for the existence of the motion of particles.

Make Connections

Communicate With your partner, discuss if Joule's evidence would be enough to convince you of the motion of particles. What other evidence have you learned that Joule could have included in his argument?

On Matter, Living Force, and Heat

...It will perhaps appear to some of you something strange that a body apparently quiescent should in reality be the seat of motions of great rapidity; but you will observe that the bodies themselves, considered as wholes, are not supposed to be in motion. The constituent particles, or atoms of the bodies, are supposed to be in motion, without producing a gross motion of the whole mass. These particles, or atoms, being far too small to be seen even by the help of the most powerful microscopes, it is no wonder that we cannot observe their motion. There is therefore reason to suppose that the particles of all bodies, their constituent atoms, are in a state of motion almost too rapid for us to conceive, for the phenomena cannot be otherwise explained. The velocity of the atoms of water, for instance, is at least equal to a mile per second of time. If, as there is reason to think, some particles are at rest while others are in motion, the velocity of the latter will be proportionally greater. An increase of the velocity of revolution of the particles will constitute an increase of temperature, which may be distributed among the neighboring bodies by what is called conduction—that is, on the present hypothesis, by the communication of the increased motion from the particles of one body to those of another. The velocity of the particles being further increased, they will tend to fly from each other in consequence of the centrifugal force overcoming the attraction.

Source: The scientific papers of James Prescott Joule by Joule, James Prescott, 1818-1889; Physical Society (Great Britain); Scoresby, William, 1789-1857; Playfair, Lyon Playfair, Baron, 1818-1898; Kelvin, William Thomson, Baron, 1824-1907. "The scientific papers of James Prescott Joule," *Internet Archive*, January 01, 1884, <https://archive.org/details/scientificpaper01joule>.

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COLLECT EVIDENCE

Think about the wood and metal blocks. How could the two blocks have energy? Record your evidence (A) in the chart at the beginning of the lesson.

What happens to a liquid when kinetic energy changes?

There is no way to see how fast particles are moving. Could you tell if the metal or wood block had more energy? One might have felt colder than the other. Is how hot or cold something feels a way to measure how much energy an object has? Let's investigate more!

INVESTIGATION

On the Rise

 **GO ONLINE** Watch the video *Rising Levels* to investigate how liquids behave when heated. Record your observations below.



Explain the relationship between kinetic energy of the particles and the volume of a liquid.

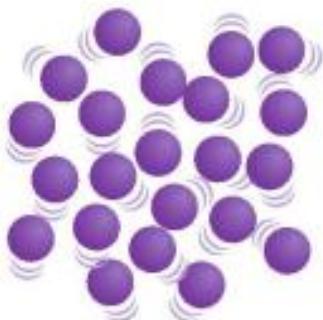
Energy and Volume As the temperature of a material increases, its particles move faster. They collide with each other more often and push each other farther apart. The increase in volume of a material when particle motion increases is known as **thermal expansion**. The opposite can also occur. A substance can lose kinetic energy and the particles will move slower. As they move slower, they collide with each other less often, which causes the substance to take up less space. This is known as thermal contraction.

Thermal contraction happens when particle motion decreases and causes the particles to occupy less volume.



THREE-DIMENSIONAL THINKING

On the right, sketch a diagram to **model** what the particles on the left would look like if they went through thermal expansion. Circle the model that has more kinetic **energy**.



Energy and Temperature The property of thermal expansion and contraction can be used to measure temperature. **Temperature** is the measure of the average kinetic energy of the particles in a material. The temperature of a substance depends on how much kinetic energy the particles that make up the material have. The lower the kinetic energy of the particles, the lower the temperature of the substance. One way to measure the relative amount of kinetic energy or speed of the particles is by measuring how much the substance expands or contracts.



GO ONLINE for additional opportunities to explore!



ENGINEERING Connection

Investigate how thermometers use thermal contraction and thermal expansion to measure temperature.

Ask questions to learn more about the history of thermometers after watching the **Animation** *How does a glass bulb thermometer work?*

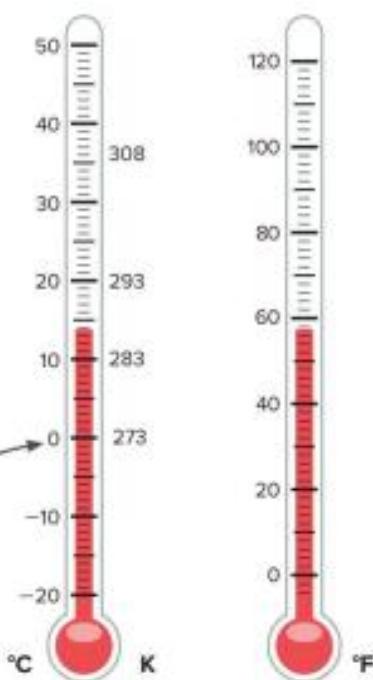
OR

Develop a model of a liquid thermometer using your own temperature scale in the **Lab Build Your Own Thermometer**.

Temperature Scales To compare temperatures you need to use the same temperature scale. A scale uses two fixed points and divides the space between the two points evenly. The Celsius scale is created with fixed points of 0°C , when water freezes, and 100°C , when water boils. Other scales include Fahrenheit and Kelvin. The Celsius scale is used by scientists worldwide.

Scientists also use the Kelvin scale. The Kelvin scale was developed to predict at what temperature particles would stop all motion. This temperature is known as absolute zero at 0 K. If a material reaches 0 K, the particles in that material would not be moving and would no longer have kinetic energy. Scientists have not been able to cool any material to 0 K.

Water's freezing point on the Celsius scale, 0°C , is equal to 32 degrees Fahrenheit.



THREE-DIMENSIONAL THINKING

1. **Construct an explanation** about the relationship between average particle speed and temperature.

2. What conclusions can you make about kinetic energy and temperature?

COLLECT EVIDENCE

How could the temperature of the wood and metal blocks be measured? Record your evidence (B) in the chart at the beginning of the lesson.

How do particles in a gas behave compared to particles in a liquid?

Think about a time when you smelled what was for lunch even though you were not near the cafeteria. The entire school did not smell the lunch at the same time. The people nearby smelled it first. The scent traveled away from the cafeteria over time. You could smell lunch because gas particles move. They move in straight lines until they collide with something, like another gas particle. These collisions change the speed and direction of the particles' movements.



INVESTIGATION

It's a Gas

 **GO ONLINE** Watch the video *Cold Balloon* and the animation *Particle Movement in Gases* to see how particles in gases behave. Complete the graphic organizer with your observations.

When the balloon was cooled, kinetic energy...

When the balloon returned to room temperature, kinetic energy...

Gas particles inside the balloon...

Gas particles inside the balloon...

Evidence of thermal...

Evidence of thermal...

Gas Particles In gases, particles move at high speeds and have high amounts of kinetic energy. Gases can expand and contract. Just like dye diffusing in a still beaker of water, being able to smell a scent over a distance is evidence for the movement of particles.

What evidence is there that particles in a solid move?

Solids, like the wood and metal you observed at the beginning of the lesson, are often described as having a definite shape. They are not fluid like liquids and gases. This means the particles in a solid do not flow past each other. Do the particles in a solid move? Let's find out!

INVESTIGATION

Still Solid

 **GO ONLINE** Watch the video *Metal Ring* to observe how particles in a solid behave when heated. Complete the graphic organizer with your observations.

When the metal ball was heated, kinetic energy...

When the metal ball returned to room temperature, kinetic energy...

Solid particles inside the metal ball...

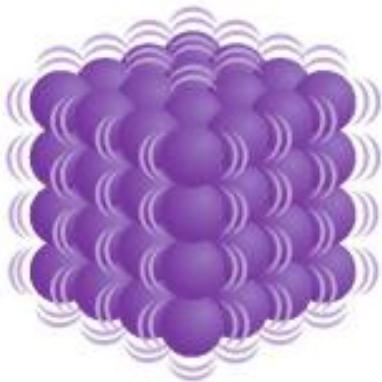
Solid particles inside the metal ball...

Evidence of thermal...

Evidence of thermal...

Based on what you saw in the *Metal Ring* video, how do you think you could model the particles in a solid?

Solid Particles The particles in a solid do not have the same freedom to move around like liquid and gas particles. In a solid, the particles vibrate back and forth in place. Since solid particles only vibrate, they have low amounts of kinetic energy. Expansion and contraction in solids does occur. However, it is less noticeable because the particles are holding each other in place.



COLLECT EVIDENCE

How could models of the particles in the wood and metal blocks show why one felt colder than the other? Record your evidence (C) in the chart at the beginning of the lesson.

How does the total amount of a substance affect its energy?

You have learned that particles have kinetic energy due to motion. Kinetic energy can be measured by comparing temperatures of substances. Kinetic energy is just one part of the total energy that a substance contains. In this lab you will add different amounts of water at different temperatures to the same amount of room temperature water. How do you think this will affect the kinetic energy of the water? Let's see what happens.

LAB In Hot Water

Safety



Materials

beakers (4)
room temperature water
30°C water
50°C water
thermometers (2)
graduated cylinder
balance
stopwatch

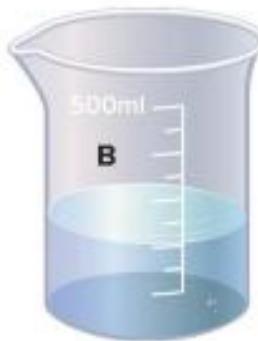


Procedure

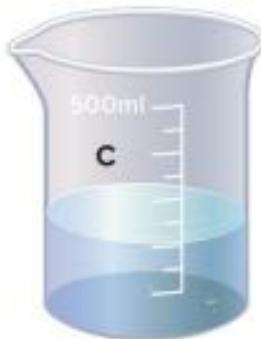
1. Read and complete a lab safety form.

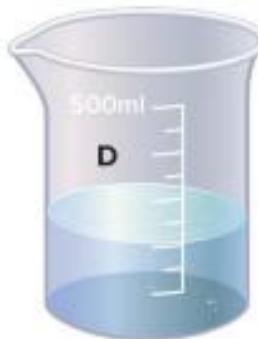
Predict the relative temperatures of the two beakers. Each beaker contains 200 g of room temperature water. 100 g of 30°C water is added to Beaker A. 20 g of 30°C water is added to Beaker B. Record your predictions of the temperatures after the water is added by entering $>$, $=$, or $<$ on the line below.





2. Test your prediction. Label one beaker A and one beaker B. Fill each beaker with 200 g of room temperature water. Measure the temperature of the water in each beaker and record the measurements in the Data and Observations section on the next page.
3. Measure 100 g of 30°C water. Add to beaker A. Measure the temperature of the water after 1 min. Record your measurement.
4. Measure 20 g of 30°C water. Add to beaker B. Measure the temperature of the water after 1 min. Record your measurement.
5. Make another prediction. Again each beaker starts with 200 g of room temperature water. 100 g of 30°C water is added to beaker C. 20 g of 50°C water is added to beaker D. Predict the relative temperatures of the two beakers. Record your predictions of the temperatures after the water is added by entering $>$, $=$, or $<$ on the line below.





7. Test your prediction from the previous page. Fill each beaker with 200 g of room temperature water. Measure and record the temperature of the water in each beaker in the Data and Observations section below.
8. Measure 100 g of 30°C water. Add to beaker C. Measure the temperature of the water after 1 min. Record your measurement.
9. Measure 20 g of 50°C water. Add to beaker D. Measure the temperature of the water after 1 min. Record your measurement.
10. Follow your teacher's instructions for proper cleanup.



Data and Observations

	Beaker A	Beaker B	Beaker C	Beaker D
Initial Temperature of 200 g Water				
	100 g of 30°C Water Added	20 g of 30°C Water Added	100 g of 30°C Water Added	20 g of 50°C Water Added
Final Temperature 1 min After Additional Water Added				

Analyze and Conclude

11. Return to your predictions. Develop an explanation for any similarities or differences between your predictions and the results.

Analyze and Conclude, continued

12. What claim can you make about the relationship between mass and energy? Use reasoning to explain how the evidence supports your claim.



THREE-DIMENSIONAL THINKING

A student left their half-full water bottle out in the Sun all day and would like to cool it down. They could add cool tap water to fill up their water bottle or they could add a small amount of cold water from the refrigerator. Present an **argument** on which option you would recommend. Support your recommendation with **evidence**.

Energy and Mass Two substances have the same average kinetic energy by being at the same temperature. When one substance has more particles, that substance has more energy. For example, there are five times as many water particles in 100 grams of water than in 20 grams of water. If the temperatures of the two water samples are the same, the sample with more mass will contain more total energy. The more particles present, the more total energy present in a substance.

COLLECT EVIDENCE

How do the masses of the wood and metal blocks affect how much energy they have? Record your evidence (D) in the chart at the beginning of the lesson.



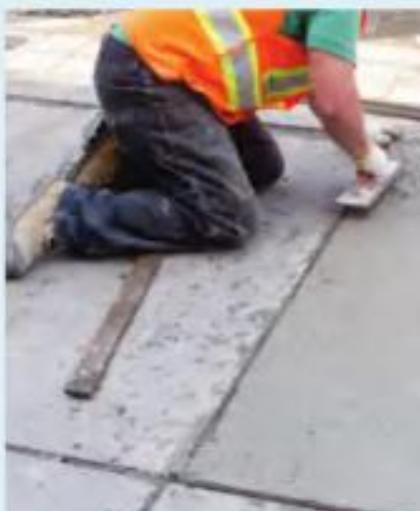
A Closer Look: Thermal Expansion in Solids



The changes to particles at the unobservable level lead to changes you can see. You learned that thermal expansion occurs in gases, liquids, and solids. Scientists have used their knowledge of thermal expansion to create thermometers. Hot air balloons are able to float because of thermal expansion. Are there any negative effects to thermal expansion?

Yes, thermal expansion can have negative effects. Two common areas where engineers take steps to guard against thermal expansion are bridges and sidewalks. Look at the photo of the Golden Gate Bridge above. What looks like a metal grate near the bottom of the inset photo is an expansion joint. This joint allows for the metal to expand during high temperatures and for the metal to contract when it is cooler.

In the photo on the right, a construction worker is adding expansion joints to concrete. Sidewalks, roads, and parking lots made of concrete are places where the effects of thermal expansion and contraction can be observed. Cracked concrete is a place where thermal expansion has occurred.



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(b) David R. Frazier Photography, Inc./Alamy Stock Photo, (b) Alamy
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It's Your Turn

 **ENGINEERING Connection** When engineers build new bridges, how do they know how far the joint must be able to move? What criteria and constraints drive their decision? How do climate, natural resources, and economic conditions affect the solution? Research this scenario or another question that you have about thermal expansion. Create a digital presentation to share your findings.



LESSON 1

Review

Summarize It!

1. Relate kinetic energy to the speed of particles.

No speed	→	kinetic energy
Greater mass	→	kinetic energy
Greater speed	→	kinetic energy

Model each statement above. Model the first statement as solid particles, the second statement as liquid particles, and the last statement as gas particles.



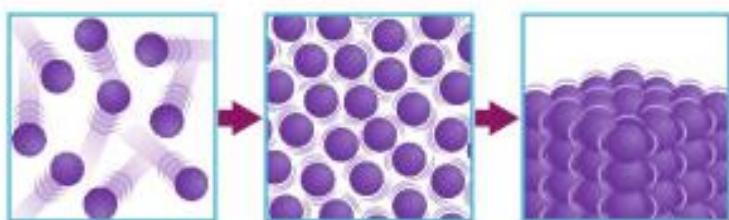
Three-Dimensional Thinking

Some students want to demonstrate thermal expansion. They devise the following method: A large black balloon is taken to a shady area and filled with cool air. The balloon is then taken to a bright, sunny location. After a short time, the balloon begins to expand.

3. What explanation does this investigation verify?

- A** A balloon filled with cool air will rise into the atmosphere.
- B** As particles gain energy, the material takes up more space.
- C** The air inside the balloon lost energy.
- D** The sunlight caused the air in the balloon to contract.

Examine the model below. The particles are undergoing a change in energy.



4. Which statement best describes what is taking place in the images?

- A** The kinetic energy of the particles on the right is the greatest of the three images of particles.
- B** The particles in the middle have more kinetic energy than the particles on the right.
- C** The particles in the middle have less space between them than the particles on the left, which means they have more kinetic energy.
- D** Energy was added to the particles on the left to give them more energy than the particles in the middle.

Real-World Connection

5. **Justify** Valdez notices that a wooden door in his house is difficult to open in the summer, but not in the winter. Valdez explains to Tony that the temperature of the door changes throughout the year. Tony says there is no way to measure the temperature of a solid because solids do not have a lot of thermal expansion. Valdez disagrees. Develop an argument supporting or opposing Tony's claim. Support your argument with at least two pieces of evidence.

6. **Synthesize** Wade could tell it was the night before trash pickup. The garbage can stank! What was it about summer that made the trash smell so bad, but the odor wasn't as bad during the winter months? Construct an explanation that details the role particle energy plays in smell.

Still have questions?

Go online to check your understanding about the particles that make up matter.

REVISIT SCIENCE PROBES

Do you still agree with the statement you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that statement now.

EXPLAIN THE PHENOMENON



Revisit your claim about why some materials feel colder than others. Review the evidence you collected. Explain how your evidence supports your claim.

START PLANNING

STEM Module Project
Engineering Challenge

Now that you've learned how the motion of particles affects a substance, go to your Module Project to determine the criteria your device will have to meet.

Keep in mind that your device will need to heat water without using open flames.



LESSON 2 LAUNCH

What's the Difference?



Five friends were talking about the differences among solids, liquids, and gases. They each agreed that the differences have to do with the particles in each type of matter. However, they disagreed about which differences determine whether the matter is a solid, liquid, or gas. This is what they said:

Gwyneth: I think it has to do with the number of particles.
George: I think it has to do with the shape of the particles.
Hoda: I think it has to do with the size of the particles.
Natalie: I think it has to do with the movement of the particles.
William: I think it has to do with how hard or soft the particles are.

With whom do you agree most? _____

Explain why you agree with that friend.

You will revisit your response to the Science Probe at the end of the lesson.

LESSON 2

States of Matter

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ENCOUNTER THE PHENOMENON

Why does gallium change states in this person's hand?



GO ONLINE

Watch the video *Metal: Gallium* to see this phenomenon in action.

After watching the video and observing how the metal gallium acts, record your observations in the space below.

EXPLAIN THE PHENOMENON

Gallium changes its state of matter from solid to liquid in someone's hand. Think about other substances that you are familiar with that change state. Ice melts in the Sun, and soup steams when it boils. Are you starting to get some ideas on why materials change state? Use gallium as an example to make a claim about what causes a substance to change its state.

CLAIM

Gallium changes state because...

COLLECT EVIDENCE

as you work through the lesson.
Then return to these pages to record your evidence.

EVIDENCE

- What evidence have you discovered to explain the temperature during a change of state?
- What evidence have you discovered to explain how potential energy and particle attraction affect changes of state?

MORE EVIDENCE

C. What evidence have you discovered to explain how melting and boiling points compare for different substances?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Gallium changes state because...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

What happens to temperature during a change of state?

When the gallium was first picked up, it was at room temperature. Your body temperature is much higher than room temperature. What happens when the gallium is warmed by your hand?

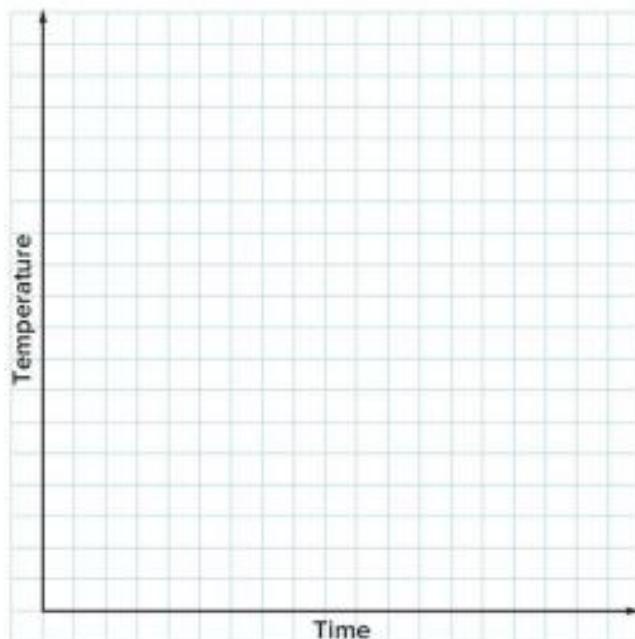


Want more information?

Go online to read more about energy and states of matter.

LAB Phase Changes

When energy is added to a solid, such as ice, the energy increases the speed of the particles by increasing the kinetic energy of the particles. Ice eventually melts to liquid water when heated. On the graph below, draw a line to predict what will happen to the temperature of ice as it melts.



Safety



Materials

crushed ice	stirring rod
beaker	hot mitts
thermometer	hot plate
stopwatch	

Procedure

1. Read and complete a lab safety form.
2. In the Data and Observations section below, create a data table to record the temperature of the ice and your observations every 30 seconds.
3. Fill the beaker $\frac{3}{4}$ full of crushed ice.
4. Record the temperature of the ice.
5. Set the beaker on a hot plate. Turn on the hot plate to medium-high.
6. Hold the beaker with a hot mitt. Use the stirring rod to stir the ice before you record the temperature.
7. Record the temperature every 30 seconds until the temperature reaches 50°C . Record your observations. Be sure to include which states of matter are present.
8. When the temperature reaches 50°C , turn off the hot plate.
9. Follow your teacher's instructions for proper cleanup.

Data and Observations



Analyze and Conclude

10. Analyze the data overall. Explain any patterns that you notice.



11. Explain what you measured, and how you measured it.

12. How did you determine which units to use, and why?

13. **MATH Connection** Determine the mean temperature for when any ice was present. What might this number represent?

14. **MATH Connection** Determine the mean absolute deviation for when any ice was present. How can the mean deviation be improved?

Changes Between Solids and Liquids When the temperature of the ice reached 0°C, the solid ice began to change to a liquid. While a substance is melting or freezing, the temperature remains constant until the change of state, or phase change, is complete. The point at which a substance changes between a solid and a liquid is referred to as the melting point or the freezing point. The melting point and the freezing point are always the same for a given substance.

When the ice changed to a liquid, the temperature remained constant. What do you think happens when water changes to a gas?

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

INVESTIGATION

Next Phase

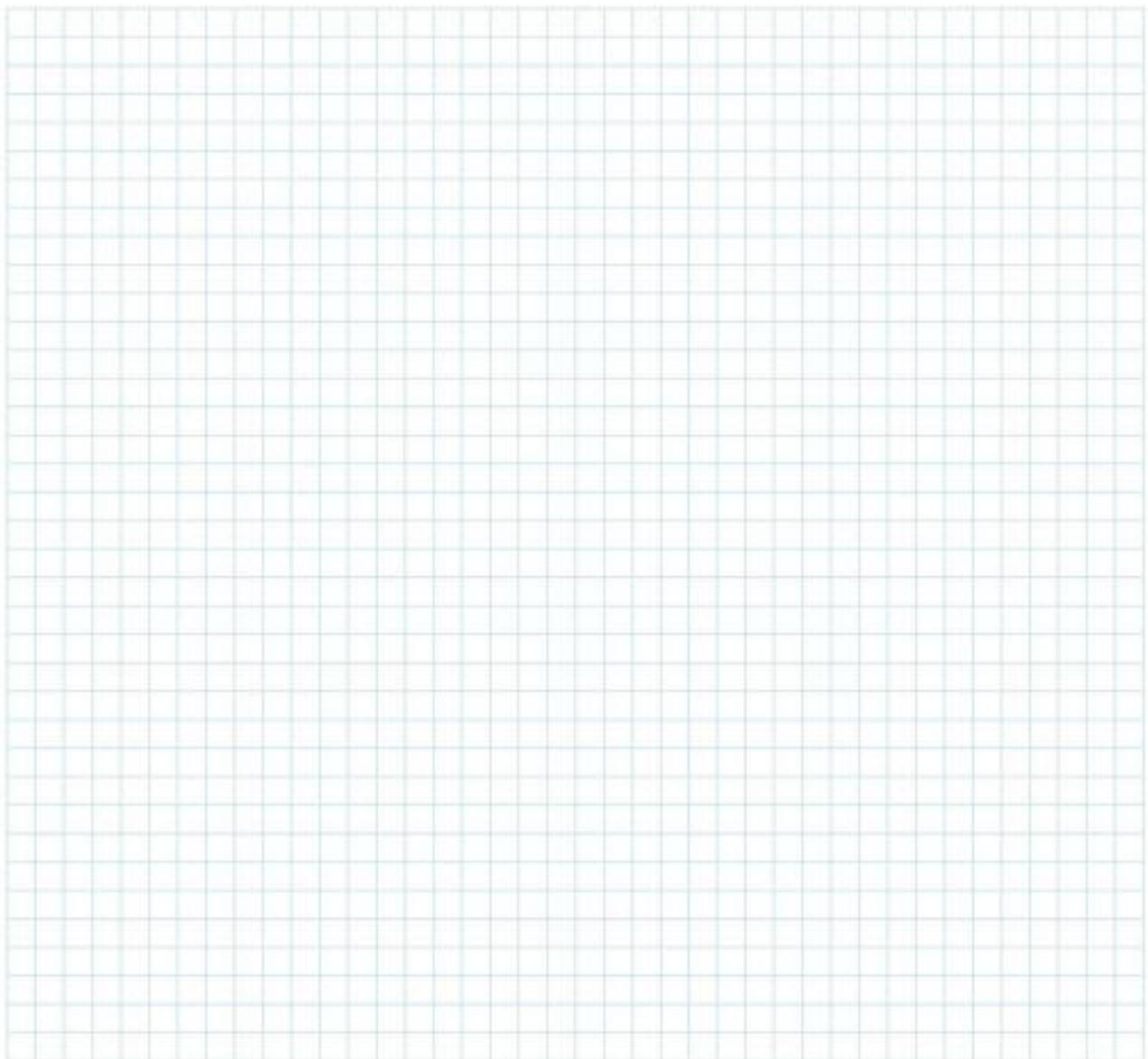
Another group of students continued the experiment to see if this pattern was the same when a liquid changes to a gas. The students examined the temperature of a beaker on a hot plate starting at 50°C and continuing until the water was boiling. Their data and observations are recorded in the table below.



Time (min)	Temperature (°C)	Observations
0:00	50.8	Liquid
0:30	60.5	Liquid
1:00	67.0	Liquid
1:30	74.4	Liquid
2:00	81.5	Liquid
2:30	88.0	Liquid
3:00	93.3	Liquid + bubbles at bottom of beaker
3:30	100.3	Liquid + boiling
4:00	100.9	Liquid + boiling
4:30	101.0	Liquid + boiling
5:00	101.1	Liquid + boiling
5:30	100.7	Liquid + boiling
6:00	100.9	Liquid + boiling
6:30	101.0	Liquid + boiling
7:00	100.9	Liquid + boiling

MATH Connection

1. Plot the temperature and time data from the Lab *Phase Changes* and the Investigation *Next Phase* on the grid below. Plot temperature on the vertical axis and time on the horizontal axis. Label the axes and add a title.
2. For each data set, draw a line that goes through the points.
3. Label the data with the states of matter that were present.



4. Identify any patterns and trends. Is this a linear relationship?

5. Develop a claim supported by evidence and reasoning on what is occurring when only a liquid is present.

6. What explanation can you make about when two states of matter are present at the same time based on the evidence?

7. If you continued to heat the water after it turned into a gas, what do you think would happen to the temperature? Explain your answer.

8. The glass is melting in the furnace. Explain why the temperature of the glass is not rising.

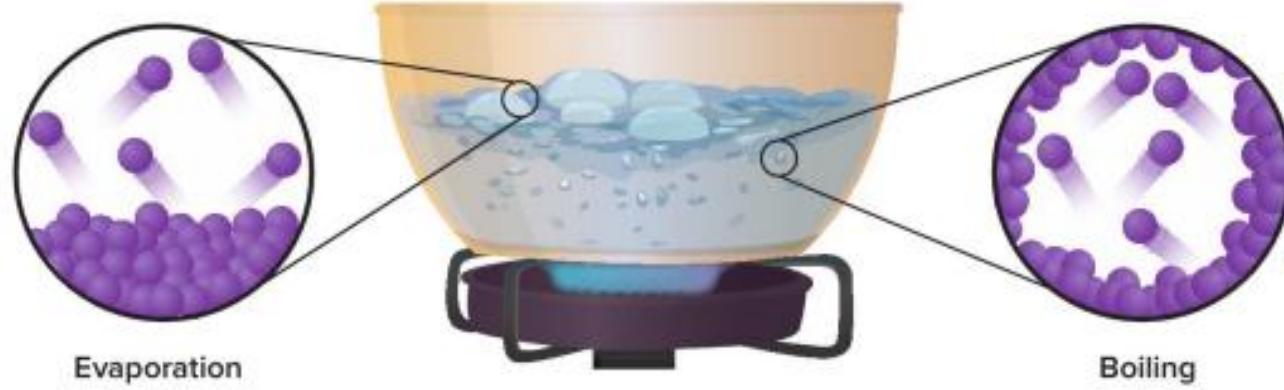


Changes Between Gases and Liquids When the temperature of a gas becomes low enough, the gas changes to a liquid. The change of state from a gas to a liquid is **condensation**.

EARTH SCIENCE **Connection** Changes between states of matter drive the water cycle. Water changes from a liquid on the ground into a gas and enters the atmosphere. When the water vapor in the atmosphere undergoes condensation, it forms clouds. The overnight condensation of water vapor often causes dew to form on blades of grass.

Vaporization The opposite of condensation is **vaporization**, the change in state from a liquid to a gas. There are two ways that vaporization occurs, boiling and evaporation.

Water condenses on grass overnight



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Evaporation	Boiling
Vaporization that occurs on the surface of a liquid is called evaporation. Evaporation can occur during boiling and at lower temperatures. A small amount of room-temperature water in a glass, for example, evaporates in a few days without ever reaching the boiling point temperature.	Vaporization that occurs within a liquid is called boiling. Boiling does not occur until a liquid is heated to its boiling point, the point where a substance changes from a liquid to a gas. Once the boiling point is reached, the continued addition of energy vaporizes the liquid. Bubbles form within a liquid as it boils.

The boiling point and the condensation point are the same for a given substance. Whether a liquid is changing to a gas or a gas is changing to a liquid, a substance will always change phases at the same temperature. While a substance is boiling or condensing, the temperature remains constant until the phase change is complete.



THREE-DIMENSIONAL THINKING

Using your understanding about the **patterns** between vaporization and condensation, **explain** why the boiling point and the condensation point are the same temperature.

COLLECT EVIDENCE

How does what happens to temperature as a substance changes state help explain why gallium melts in someone's hand? Record your evidence (A) in the chart at the beginning of the lesson.

What happens to particles and energy during a change of state?

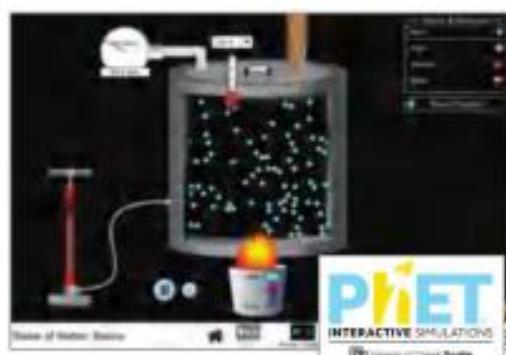
As you have observed, when the temperature rises, gallium will change state. Think about the particles in gallium. How do they move during a phase change?

INVESTIGATION

Changing Energy

 **GO ONLINE** Explore the PhET interactive simulation *States of Matter: Basics*. Explore the simulation on your own. When you are finished, reset the simulation, and then follow the instructions below.

1. Return to the home page and go to Phase Changes tab.
2. Add energy by switching the toggle to Heat.



3. In the graphic organizer below, circle the word that best describes what happens as heat is added to the solid.

Temperature of solid	Speed of particles	Distance between particles
increased	increased	increased
decreased	decreased	decreased
stayed the same	stayed the same	stayed the same

Particle Arrangement If energy is continually added to a substance, there reaches a point where the particles cannot go any faster without changing to another state of matter. Recall that particles in gases are fast moving and spread out from each other. In liquids, particles are closely packed but can slide past each other. In solids, the particles are closely packed and held in a rigid formation. The reason each state of matter has different shapes is because of the particle attractions in each state of matter.

Particle Attraction When energy is added and the particles cannot move any faster in the current state of matter, the energy is used to overcome the attraction between particles and causes a change of state. The additional energy increases the potential energy of the particles. **Potential energy** is stored energy due to the interactions between particles or objects. The potential energy increases as the distance between particles increases. Conversely, the potential energy decreases as the distance between the particles decreases. The particles that are farther apart have greater potential energy. The potential energy of the particles, determined by the state of matter present, contributes to the total energy of a substance.

Kinetic Energy	Potential Energy
Relates to particle speed	Relates to the distance between particles/strength of attractions between particles
Measured by temperature of substance	Measured by state of matter
Increases as particle speeds increase	Increases as distance between particles increases
Decreases as particle speeds decrease	Decreases as distance between particles decreases
Increases as temperature increases	Increases as state of matter changes from solid to liquid to gas
Decreases as temperature decreases	Decreases as state of matter changes from gas to liquid to solid



THREE-DIMENSIONAL THINKING

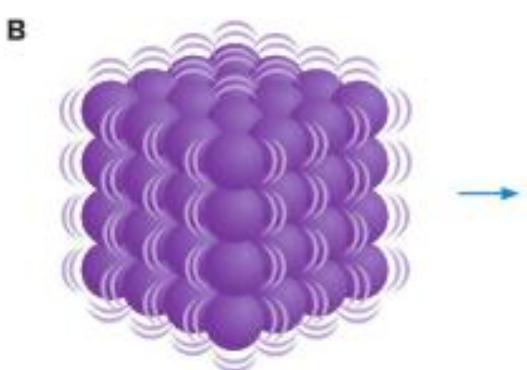
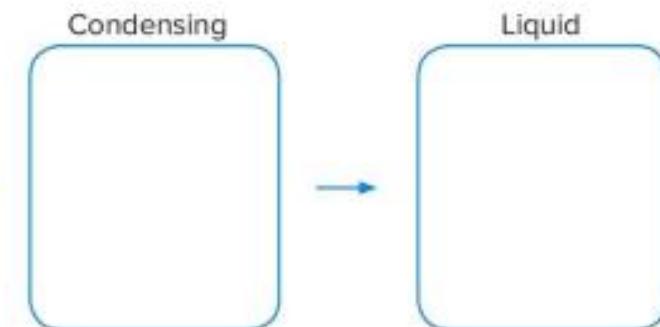
For each example:

1. Complete the **model** of the particles.
2. Indicate how potential **energy** is changing (increasing or decreasing).
3. Indicate how the attractive forces are changing (increasing or decreasing).



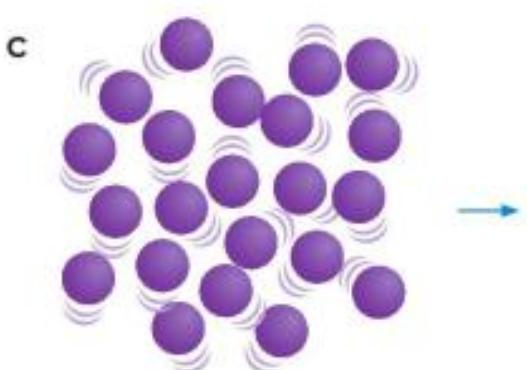
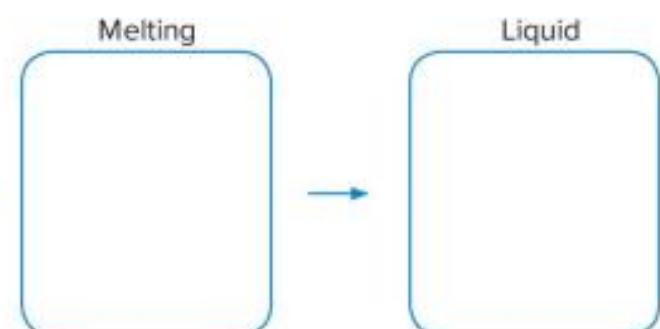
Potential Energy = _____

Attractive Forces = _____



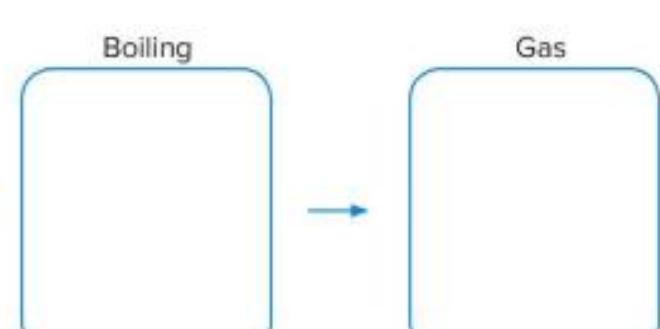
Potential Energy = _____

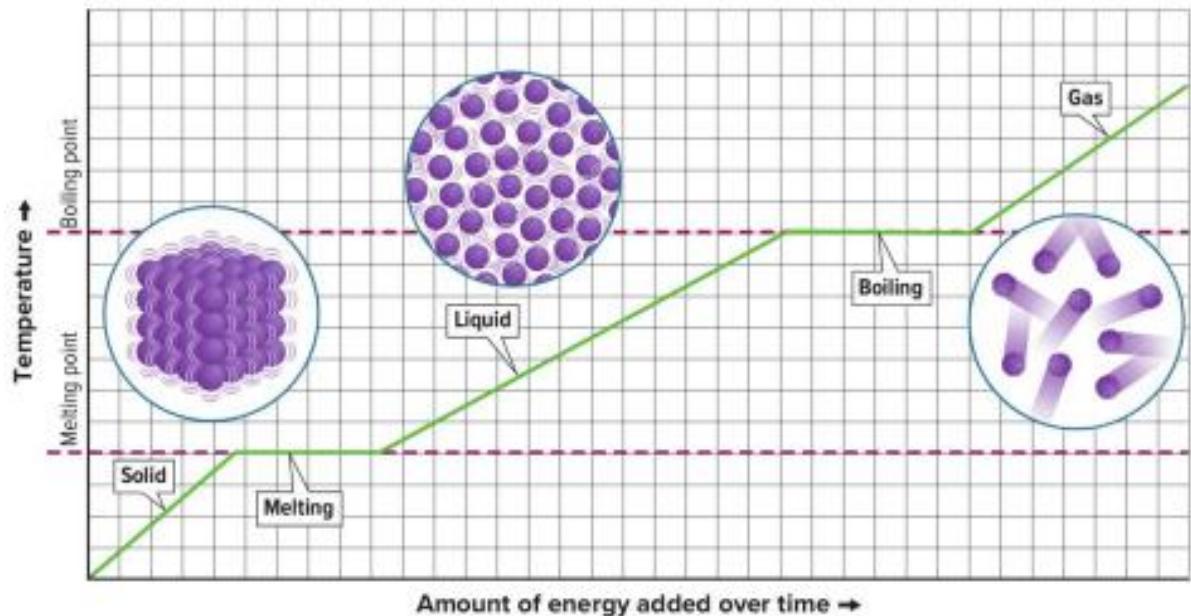
Attractive Forces = _____



Potential Energy = _____

Attractive Forces = _____





Heating Curves The graph above is the heating curve for water. Just as in the graphs you created, it shows what happens to temperature as energy is added to a substance. As energy is transferred to a material, temperature increases when the state of the material is not changing. The kinetic energy of the particles increases. This increases the speed of the particles.

When a substance is changing state, temperature stays the same at the melting and boiling. The potential energy of the particles increases. This increases the distance between the particles.



THREE-DIMENSIONAL THINKING

Construct an **argument** on how the existence of potential **energy** between particles supports or opposes the shape of a heating curve.

COLLECT EVIDENCE

How does the existence of potential energy and the attractions between particles help explain why gallium exists as different states of matter? Record your evidence (B) in the chart at the beginning of the lesson.

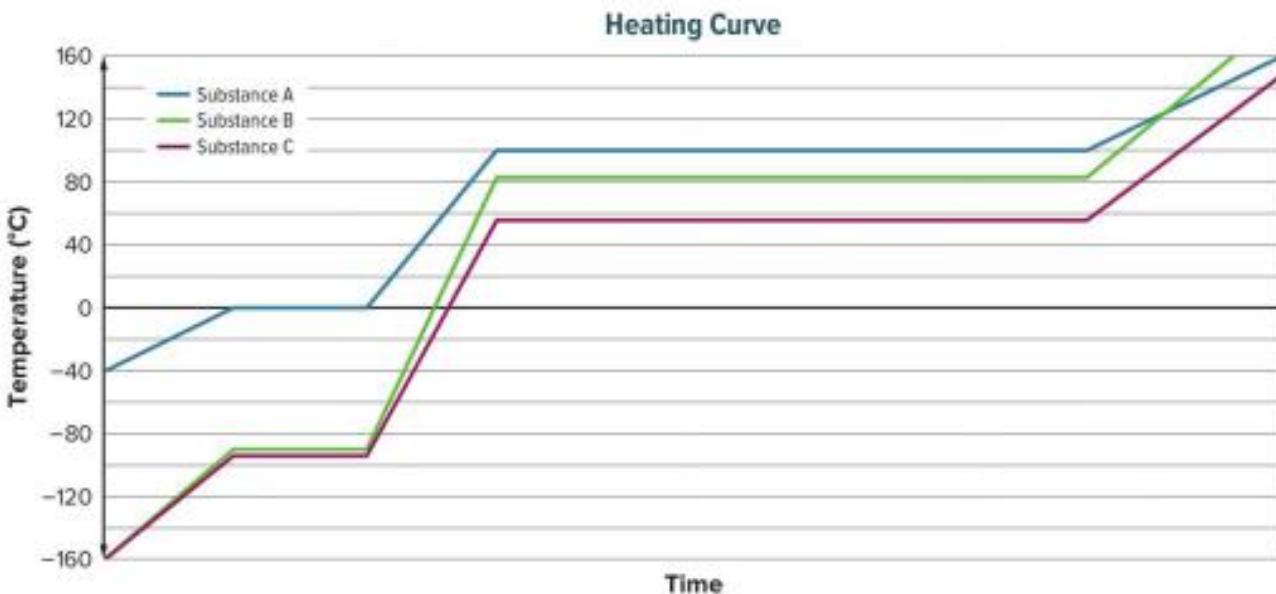
How do the melting and boiling points of different substances compare?

You know that ice melts at 0°C and liquid water boils at 100°C. Based on what you have learned so far, think about what you might expect the melting point of gallium to be.

INVESTIGATION

Turn Up the Heat

A group of students collected data using a similar procedure as the lab *Phase Changes*. They tested 100 mL of three different substances. The plot below was compiled from their data.



1. What patterns do you notice about the plot?

2. Complete the table below using the data plot.

Substance	Melting Point (°C)	Boiling Point (°C)
A		
B		
C		

3. Make a claim about the melting and boiling points of different substances supported by evidence and reasoning.

4. At which temperatures are the potential energies of substances A, B, and C changing?

Particles and Melting Points Each substance has a unique melting and boiling point temperature. This is because the particles that make up each substance have different attractions for each other. The more attracted these particles are to each other, the more energy it takes to increase the distance between particles. This results in higher melting and boiling points. The type of particles that make up a substance affect how much energy is needed to cause a change of state. This is why different substances are in different states at the same temperature.



Water, butter, and aluminum change state at different temperatures.

COLLECT EVIDENCE

Why does gallium change from a solid to a liquid at a different temperature than ice changes to liquid water? Record your evidence (C) in the chart at the beginning of the lesson.

What factors determine the total energy of a substance?

The particles that make up gallium are constantly in motion. This means that the gallium, even when solid, has energy. Think about what factors could change how much energy a substance has.

INVESTIGATION

Energy Factors

1. Identify which substance has the most energy. For each pair, enter $>$, $=$, or $<$ on the line.

Substance: X
Mass: 50 g
Temperature 50°C
State: Liquid



Substance: X
Mass: 50 g
Temperature 100°C
State: Liquid



Substance: X
Mass: 50 g
Temperature 50°C
State: Liquid



Substance: X
Mass: 5 g
Temperature 50°C
State: Liquid



Substance: X
Mass: 50 g
Temperature 50°C
State: Liquid



Substance: X
Mass: 50 g
Temperature 50°C
State: Solid



Substance: X
Mass: 50 g
Temperature 50°C
State: Liquid



Substance: Y
Mass: 50 g
Temperature 50°C
State: Liquid



2. If you marked any pair of substances "need more information", explain why.

Thermal Energy The total energy of a substance depends on:

- the kinetic energy or the speed of the particles (measured by temperature),
- the potential energy or the arrangement of the particles (determined by state of matter),
- the total number of particles in the substance (measured by the mass of the substance), and
- the type of matter that makes up the substance.

Thermal energy is the total energy of a system that is dependent on the number of particles in the system, the state of the material, and the temperature. Thermal energy is not the same as temperature. Temperature is the measure of the average kinetic energy of the particles. The molten, or liquid, metal to the right is the same temperature as the metal it is flowing over. However, the liquid metal's particles have more kinetic and potential energy.



THREE-DIMENSIONAL THINKING

Explain how the particle model of matter compares to the results from the Lab *Phase Changes*.

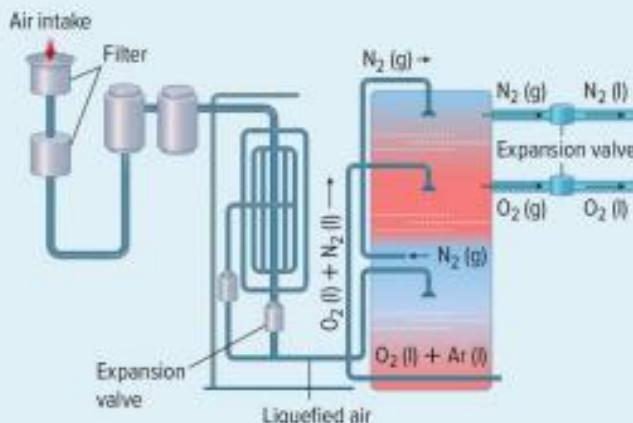
A Closer Look: Fractional Distillation



Engineering Connection The components of dry air are nitrogen (78 percent), oxygen (21 percent), and other gases (1 percent total). When the components are separated by differences in boiling points, the method of separation is called fractional distillation.

1. Soot and dirt are removed from air by filters.
2. In a heat exchanger, the air releases heat to the cooler surrounding fluid.
3. The cooled, compressed air passes through a nozzle into a chamber of larger diameter. As the air moves through the chamber, it cools. The temperature difference is so great that the air liquefies.
4. The liquefied air flows over several heated trays and is warmed to the boiling point of nitrogen (-195.8°C). Most of the nitrogen, with a trace of oxygen, vaporizes.
5. The liquid oxygen and remaining liquid nitrogen are collected and passed into an upper chamber for another distillation at a higher temperature.
6. After passing through more chambers, the separated gases are liquefied again and bottled as liquid nitrogen and oxygen.

Liquid oxygen and liquid nitrogen are shipped in special insulated containers at temperatures slightly lower than their boiling points.



It's Your Turn

Research and Report The last 1 percent of air is mainly argon gas. This argon is difficult to remove from the liquid oxygen with a fractional distillation process. Why might this be? Make a report of the problem and share your findings with your class.

Review

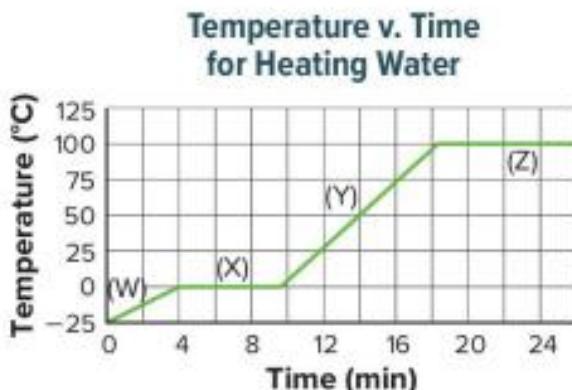
Summarize It!

1. **Organize** Create a graphic organizer that relates thermal energy, temperature, particle motion, and state of matter.



Three-Dimensional Thinking

The heating curve for water is shown below.



2. Analyze the heating curve. Which area or areas of the curve show a change in the potential energy of the particles?

- A W
- B W and X
- C X and Z
- D Y



3. A scientist was working with substance Y. Which of the following does not represent an increase in thermal energy?

- A The temperature of the substance rose by 10°C.
- B The volume of the substance increased by 10 mL.
- C The mass of the substance increased by 10 g.
- D The substance changed from a liquid into a solid.

Real-World Connection

4. **Explain** Think of a time that you noticed a change of state. Explain what happened using the terms *temperature*, *particle motion*, and *energy*.

5. **Compare** the amount of thermal energy required to melt a solid with the amount of thermal energy released when the same liquid becomes a solid.

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Still have questions?

Go online to check your understanding about thermal energy and states of matter.

REVISIT



Do you still agree with the friend you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that friend now.

EXPLAIN THE PHENOMENON



Revisit your claim about how gallium changes state. Review the evidence you collected. Explain how your evidence supports your claim.



KEEP PLANNING

STEM Module Project Engineering Challenge

Now that you've learned about the role of thermal energy in changes of states of matter, go back to your Module Project to research technologies that use solar energy to heat foods. Use your research to start your own design for a device to heat water.

LESSON 3 LAUNCH

Hot Soup

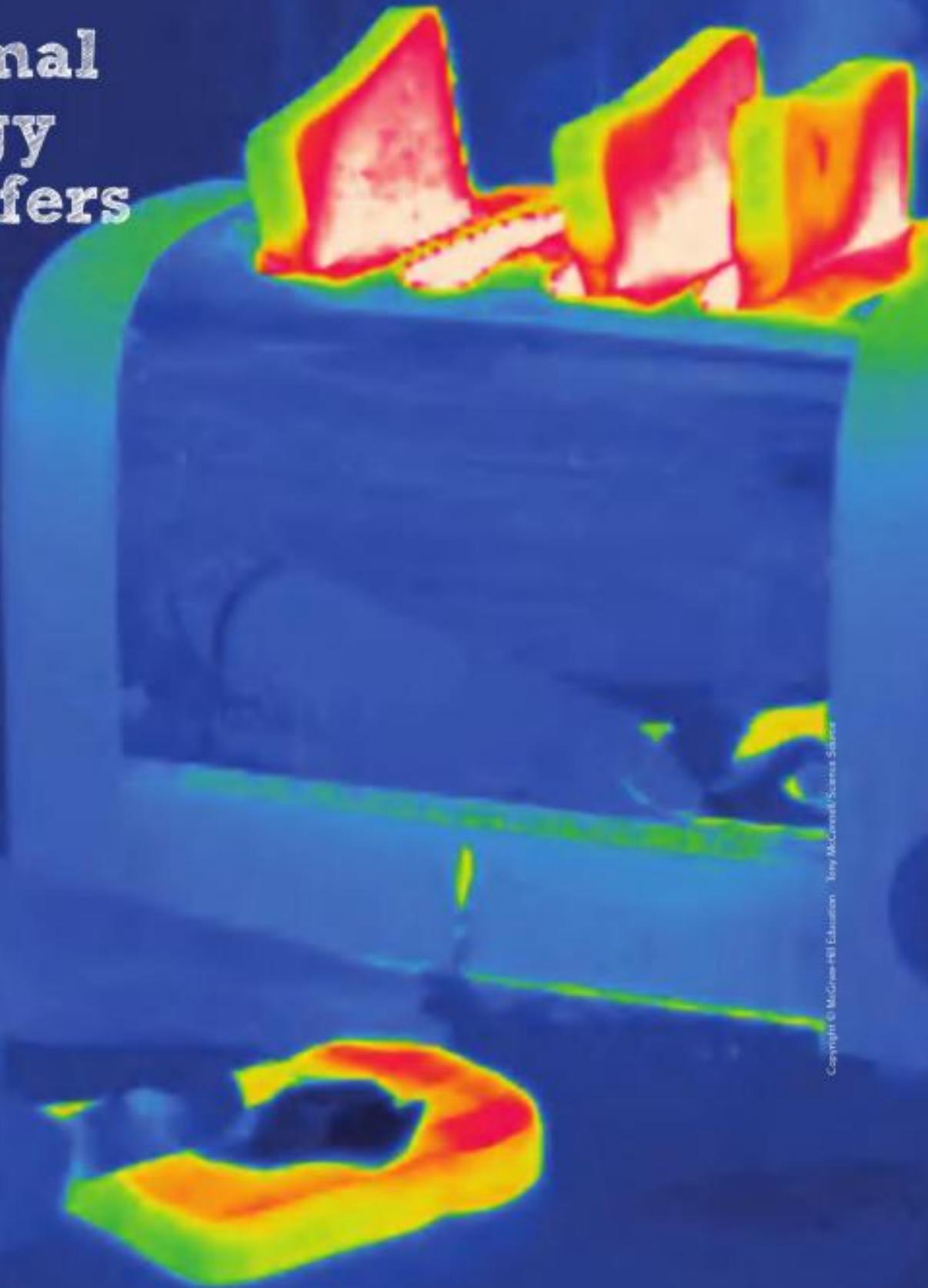


Janey had a bowl of hot soup for lunch. The soup was so hot she decided to put it in the refrigerator for a few minutes to cool it. What happened to cool the soup so Janey could eat it?

- A. The heat moved from the soup to the cold air in the refrigerator.
- B. The cold in the refrigerator moved into the hot soup.
- C. No heat or cold moved out of or into the soup. It just cooled off.

Circle the answer that best matches your thinking. Explain your thinking.
Describe what happened to cool the soup down.

Thermal Energy Transfers

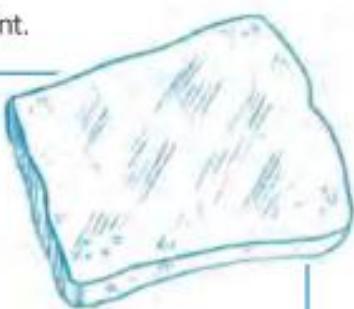


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ENCOUNTER THE PHENOMENON

How does energy flow between the toast and the environment?

Watch out, that toast is hot! It must contain a lot of energy. A thermogram shows the temperature of an object by using colors. Create a model that illustrates what you think the energy of this system is when A) the toast first comes out of the toaster and B) after the toast has been left on a plate for 30 minutes. Then, explain how the two illustrations are similar and different.



EXPLAIN THE PHENOMENON

Now that you have thought about what happens to energy as the toast cools, are you getting some ideas about the direction of heat flow from one object to another? Using the toast as an example, make a claim about how thermal energy moves in the system between the toast and the environment.

CLAIM

Thermal energy flows from...to...

COLLECT EVIDENCE

as you work through the lesson.

Then return to these pages to record your evidence.

EVIDENCE

- What evidence have you discovered to help identify the components in a system in order to explain the direction of thermal energy transfer?
- What evidence have you discovered to describe how radiation helps explain the direction of thermal energy transfer between the toast and the environment?

MORE EVIDENCE

C. What evidence have you discovered to describe how convection helps explain the direction of thermal energy transfer between the toast and the environment?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Thermal energy flows from...to...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

Where does thermal energy go?

Have you ever forgotten about food that you had heated up in the microwave? You might have needed to heat it up again because it had become cold. The microwave increased the thermal energy of the food by increasing the temperature of the food. Why did the food become cold after you forgot about it?

Want more information?

Go online to read more about thermal energy transfers.



Why did it become cold?

LAB Transferring Temperature

Safety



Materials

small beaker	cold water
large beaker	thermometers (3)
hot water	stopwatch

Procedure

1. Read and complete a lab safety form.
2. Add 200 mL of cold water to the large beaker.
3. Add 200 mL of hot water to the small beaker.
4. Record the temperatures of the water in both beakers and of the air inside the classroom in the data table on the next page.
5. Without spilling any of the water, place the small beaker inside the large beaker.
6. Record the temperatures of the water in both beakers and the air inside the classroom. Continue recording the temperatures every minute for 5 minutes.
7. Place the beakers in an undisturbed spot overnight to use later.



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Data and Observations

Time (min)	Temp. of Water in large beaker (°C)	Temp. of Water in small beaker (°C)	Temp. of Air (°C)
0			
1			
2			
3			
4			
5			

Analyze and Conclude

8. Identify any patterns in the data.

9. Why was it important to measure the temperature of the water in both beakers and the air in the classroom throughout the lab?

Systems and Energy The two beakers from the Lab *Transferring Temperature* represent a system. Systems are used to model the movement of energy. A **closed system** is a system that does not exchange matter or energy with the environment. Some situations can be thought of as closed systems, such as thermal energy transfers inside a microwave. In reality, there are no closed systems. The microwave is attached to an electrical outlet. Every physical system transfers some energy to or from its environment. An **open system** is a system that exchanges matter or energy with the environment.



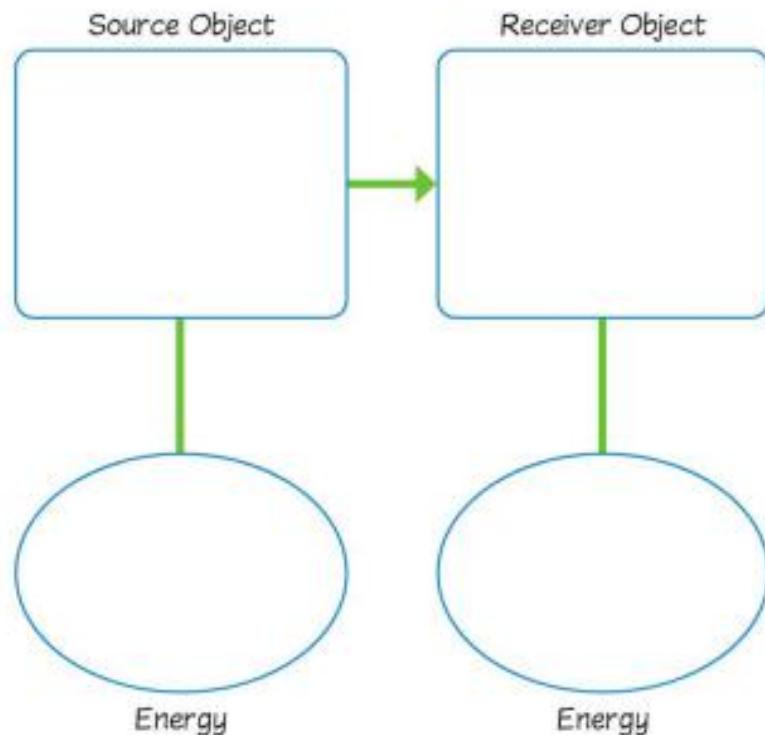
The vegetables and microwave represent a system.

Objects make up the components of a system. Energy flows between the objects. The object that provides the energy for energy transfer is called the **source object**. The object that gains the energy from the energy transfer is called the **receiver object**.



THREE-DIMENSIONAL THINKING

Use the **energy** flow diagram to **model** the components of the **system** found in the Lab *Transferring Temperature*. Identify the type of energy involved and whether the energy increased or decreased.



Direction of Thermal Energy Transfer All substances contain thermal energy. When two substances contain different amounts of thermal energy, energy can transfer between the substances. The amount of thermal energy transferred from a region of higher temperature to a region of lower temperature is **heat**. Heat can also refer to the amount of energy transferred during this process.

It is not possible to make something colder by adding "coldness" to it. A substance can only be cooled by allowing some of its energy to be transferred to a substance of a lower temperature. For example, liquid water transfers energy to the surrounding air in a freezer in order to freeze.



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THREE-DIMENSIONAL THINKING

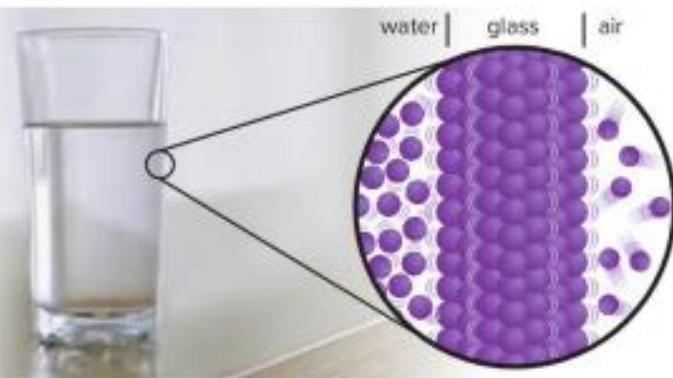
In the figure above, the water in the ice cube tray is 10°C. It is placed in the freezer at 0°C. Add arrows to the figure to **model** the direction of **energy** transfer.

Conduction Have you ever noticed that when you place a hot piece of toast on a plate, the plate becomes warmer? Thermal energy from the toast transfers to the plate through the process of conduction. **Conduction** is the transfer of thermal energy between materials by the collisions of particles. The particles in the hot toast are in contact and so collide with the particles of the plate. This causes the particles in the plate to gain thermal energy. Conduction can occur between solids, liquids, and gases.

When particles at different temperatures collide, the particle with higher kinetic energy transfers energy to the particle with lower kinetic energy. This changes the motion of both of the particles. When the energy of a substance changes, there is always another change in energy at the same time. For example, if a particle transfers or loses kinetic energy, it will move slower. If a particle gains kinetic energy, it will move faster.

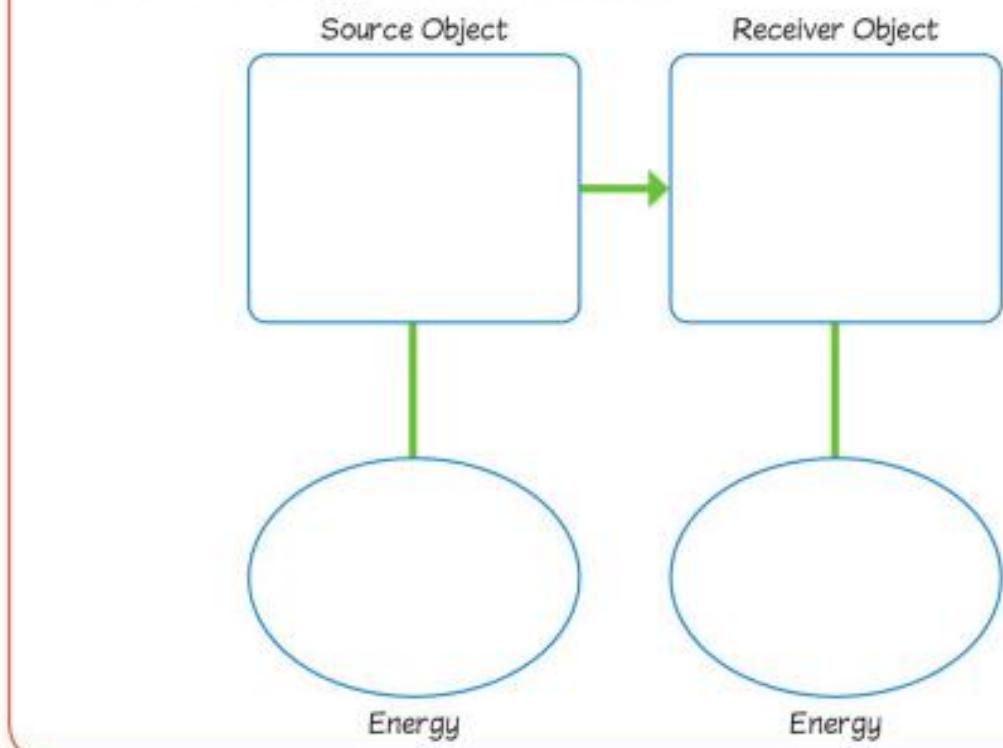
FOLDABLES®

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.



THREE-DIMENSIONAL THINKING

Look closely at the motion of the particles modeled in the image above. Use the **energy** flow diagram to **model** the components of the **system** that are transferring energy. Identify the type of energy involved and whether the energy increased or decreased.



LAB Transferring Temperature Over Time

Safety



Materials

undisturbed beakers (from the *Transferring Temperature* lab)

thermometers (3)



Procedure

1. Read and complete a lab safety form.
2. Retrieve the beakers from where they were left overnight.
3. Record the temperature of the water in the two beakers and the air in the classroom in the Data and Observations section.
4. Follow your teacher's instructions for proper cleanup.

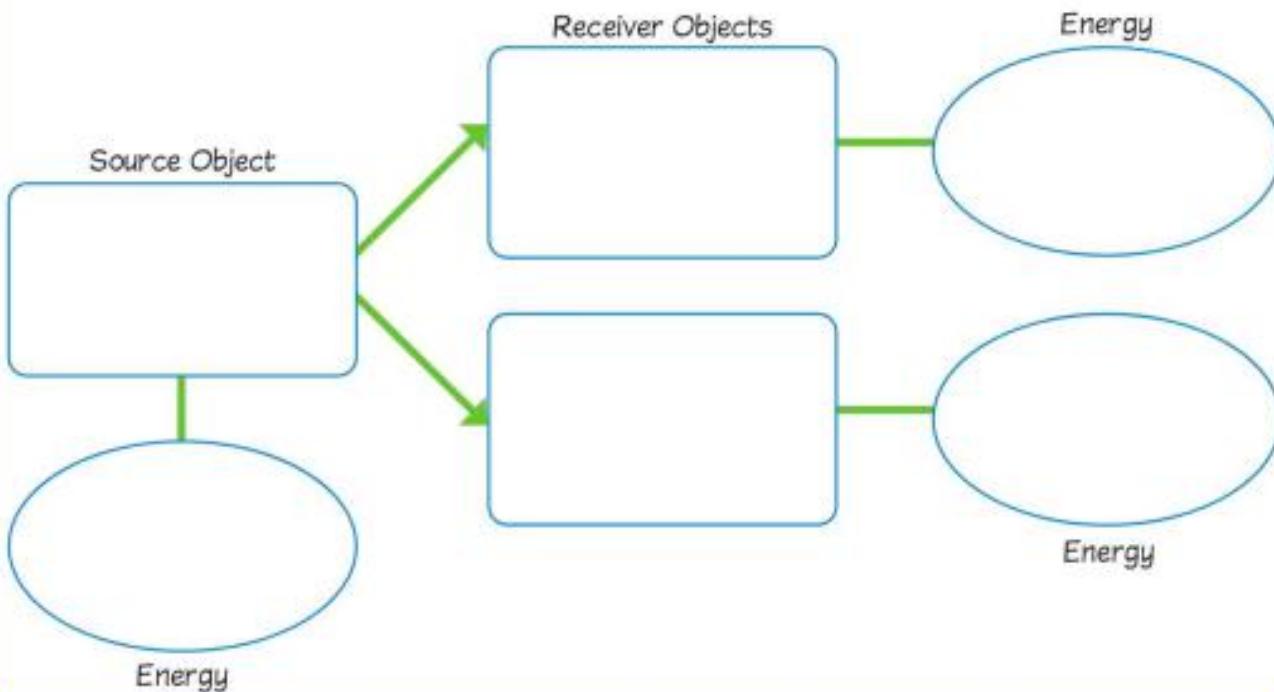
Data and Observations

Analyze and Conclude

5. What happened to the temperature of the water in the beakers?

6. How are the components of the system in this lab similar to or different from those in the previous lab?

7. Complete the energy flow diagram to identify the components of the open system, the type of energy involved, and whether the energy increased or decreased.



Thermal Equilibrium When the temperatures of materials that are in contact are the same, the materials are said to be in **thermal equilibrium**. After the materials reach thermal equilibrium, the particles that make up the water, the beaker, and the air continue to collide with each other. The particles transfer kinetic energy back and forth, but the average kinetic energy of all the particles remains the same.

COLLECT EVIDENCE

How does identifying the components in a system help explain the direction of thermal energy transfer between the toast and the environment? Record your evidence (A) in the chart at the beginning of the lesson.

How does thermal energy transfer when objects are not in contact?

How does a toaster heat the toast? If you have ever taken a look at the inside of a toaster you might have noticed that the heating coils never touch the bread. If the coils do not come into contact with the toast, then the toast cannot be heated by conduction. How else can thermal energy be transferred?



LAB Lights On

Safety



Materials

lamp
thermometers (2)
stopwatch

Procedure

1. Read and complete a lab safety form.
2. Record the air temperature with two thermometers in the Data and Observations section below.
3. Place one thermometer about 10 cm under a lamp. Place the other thermometer away from the lamp.
4. Record the temperature of each thermometer every 30 sec for 2 min. Record your observations below.
5. Follow your teacher's instructions for proper cleanup.



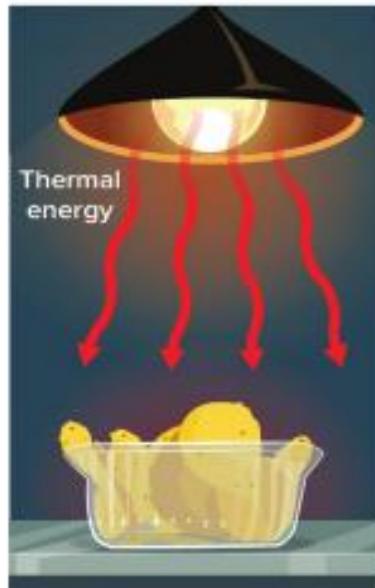
Data and Observations

Analyze and Conclude

6. What happened to the temperatures of the two thermometers?

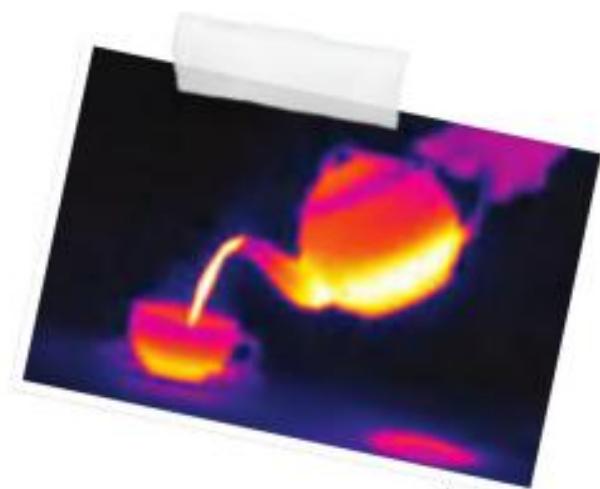
Radiation Another process that transfers energy is radiation. **Radiation** is the transfer of thermal energy from one material to another by electromagnetic waves. All matter, including the Sun, fire, and even you, transfers thermal energy by radiation. Warm objects emit more radiation than cold objects do.

A thermogram, like the one shown below and at the beginning of the lesson, is an image created by a technology that measures the radiation given off by objects. The thermogram below shows hot water pouring from a teapot into a cup. Objects giving off more radiation are shown in white, reds, and yellows, while cooler objects are shown with blues, purples, and black.



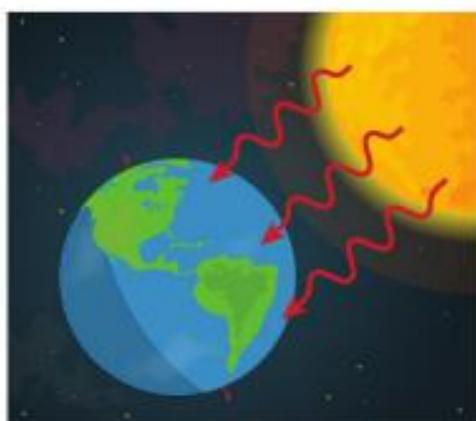
THREE-DIMENSIONAL THINKING

In the thermogram on the right, how do conduction and radiation **explain** the **energy** transfers occurring?



What's happening here?

EARTH SCIENCE Connection Thermal energy from the Sun can only travel to Earth by radiation. This is because space is a vacuum—a space that contains little or no matter. Since there is little matter in space, thermal energy cannot transfer by conduction, which requires objects to be in contact. Radiation is the method of thermal energy transfer in space. However, radiation also can transfer thermal energy through solids such as rocks, liquids like the ocean, and gases in the atmosphere.



COLLECT EVIDENCE

How does radiation help explain the direction of thermal energy transfer between the toast and the environment? Record your evidence (B) in the chart at the beginning of the lesson.

A Day in the Life of an Energy Auditor



Energy auditors use devices to take thermograms of homes.

Thermograms are used to see areas of different temperatures in a building and provide information on how well a home has been insulated. An energy auditor scans the house for thermal signatures that indicate faulty insulation.

Weak spots are normally found around windows and doors in a house. Energy auditors can sometimes detect roof leaks because wet insulation will conduct thermal energy faster than dry insulation. Scans of electrical systems can detect unusually hot electrical connections in walls. An energy auditor can use these results to improve the efficiency of heating and air-conditioning units.

Skills an energy auditor needs include an understanding of thermal energy transfers, construction and building knowledge, and heating and cooling appliance design.

Training for energy auditors can occur at one of the Weatherization Training centers across the U.S.

It's Your Turn

Research and Report Research different ways that homeowners reduce thermal energy transfer in weak spots around the home. Create a short presentation with multimedia and visual displays for a community event on how homes in your neighborhood can reduce thermal energy loss.



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How else does thermal energy transfer in liquids and gases?

Have you ever heard the saying "hot air rises"? If you hold your hand over the top of a toaster, it is warmer than if you hold your hand near the side. Why is that, and how does it relate to how thermal energy transfers?

INVESTIGATION

Rising Liquids

 **GO ONLINE** Watch the video *Groovy Lava Lamps*. Then answer the following question.

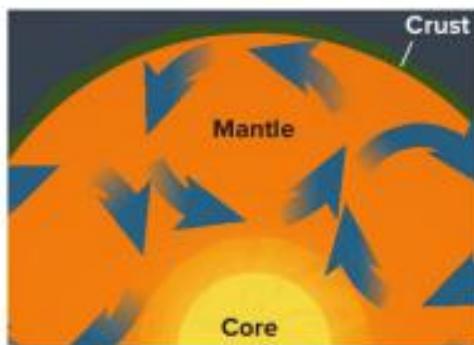
How might thermal energy transfers cause the patterns in the movement of the liquid in the lava lamp?

What patterns do you notice?



Convection Thermal energy can transfer in a third way. **Convection** is the transfer of thermal energy by the movement of particles from one part of a material to another. Convection explains why hot air rises and cooler air sinks. So as the toaster warms the air in the toaster, the air rises and moves upward into the room. Convection occurs in liquids and gases. Convection does not occur in solids because the particles in solids cannot flow.

EARTH SCIENCE Connection Convection plays an important role in the cycling of materials in Earth's systems. Convection currents circulate water in Earth's oceans and other bodies of water. Convection of thermal energy also moves air on Earth's surface and magma in Earth's interior as shown in the figure on the right.



COLLECT EVIDENCE

How does convection help explain the direction of thermal energy transfer between the toast and the environment? Record your evidence (C) in the chart at the beginning of the lesson.

Review

Summarize It!

1. **Model** Many zoos provide heat lamps for their animals, such as meerkats. Create an energy flow diagram showing the transfer of thermal energy between the animals, the heat lamp, and the environment.





Three-Dimensional Thinking

Velinda wants to verify that thermal energy moves from warmer substances to cooler substances until all the substances attain the same temperature. She writes her experimental plan after forming her hypothesis about what will happen to the temperatures at different locations throughout the system. She develops a materials list and procedure for her investigation.

Materials	Procedure	Communication
hot plate 500-mL beaker thermometers timer piece of ice water	1. Place water and ice in the beaker. 2. Take the temperature of the water at the bottom of the beaker, the center of the beaker, and the top of the beaker. 3. Start the stopwatch and record the temperature. 4. Place the beaker with water and ice on the hot plate. Turn the hot plate to medium heat. 5. Every 2 min, record the time and temperature until the water boils. 6. Continue heating and take two more temperature readings.	Create a graph with the data. Write a report that includes the hypothesis, whether the hypothesis is supported, and a conclusion statement about thermal energy movement.

2. Which lab equipment did Velinda omit from her materials list that will ensure her personal safety as she performs her experiment?

- A balance scale, candle, glass dish
- B goggles, apron, heat-resistant gloves
- C metal tongs, Bunsen burner, spark igniter
- D vent hood, fire safety handbook, eyewash station

3. Identify the independent and dependent variables of the experiment.

- A Independent: temperature; dependent: thermal energy
- B Independent: thermal energy; dependent: time
- C Independent: temperature; dependent: time
- D Independent: time; dependent: temperature

Real-World Connection

4. Illustrate Phoebe is making fruit pops. She places the liquid in the pop molds and places them in the freezer. Phoebe is wondering how the freezer can turn the liquid pops solid. Sketch a diagram showing the flow of thermal energy through all the components in the system.

Still have questions?

Go online to check your understanding about thermal energy transfers.

REVISIT



Do you still agree with the statement you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that statement now.

EXPLAIN THE PHENOMENON



Revisit your claim about the direction of thermal energy transfer between the toast and the environment. Review the evidence you collected. Explain how your evidence supports your claim.

KEEP PLANNING

STEM Module Project
Engineering Challenge

Now that you've learned about thermal energy transfers, go to your Module Project to sketch your design for your cooker technology. Make sure your design meets all the criteria and constraints of the problem, including the use of an energy source other than an open flame.



LESSON 4 LAUNCH

Is the cup hot?



Adita and his friends were learning about insulators and conductors in school. They all agree that metal, a conductor, will heat up more quickly than ceramic, an insulator. They have different ideas about how the materials will cool. This is what each friend said:

Adita: I think the ceramic will cool quicker than the metal.

Niabi: I think the metal will cool quicker than the ceramic.

Irene: I think they will both cool at the same rate.

Rafi: I think conductors and insulators have nothing to do with how a material cools, just how a material heats up.

Which student do you agree with the most? _____
Explain your ideas about conductors and insulators.

Thermal Energy Conductivity



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ENCOUNTER THE PHENOMENON

Why is this kitchenware made out of so many different materials?



GO ONLINE

Watch the video *Cooking in the Kitchen* to see this phenomenon in action.

Observe the different types of kitchenware provided by your teacher. Classify the kitchenware based on how you think it would transfer thermal energy. Illustrate your classification system in the space below. Support each classification with an explanation.

EXPLAIN THE PHENOMENON

Kitchenware is made of many different types of materials. Have you ever thought about how those different materials transfer thermal energy? Use your ideas about kitchenware to make a claim about what affects how a material transfers thermal energy.

CLAIM

Thermal energy transfers are affected by...

COLLECT EVIDENCE

as you work through the lesson.
Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain how the mass of a material in the kitchenware affects how it transfers thermal energy?

B. What evidence have you discovered to explain how the type of material in the kitchenware affects how it transfers thermal energy?

MORE EVIDENCE

C. What evidence have you discovered to explain what other properties affect how kitchenware transfers thermal energy?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Thermal energy transfers are affected by...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

How does mass affect the change in temperature of a substance?

Water boils at 100°C, but does the amount of water affect how much thermal energy is needed to start boiling? Examine the figure of the pots on the right. Will the water filling each pot boil at the same time if the energy input is the same for each burner? Let's find out!



Want more information?

Go online to read more about what affects how much thermal energy transfers.

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

LAB Massing Around

Safety



Materials

beakers (4)	room temperature water
balance	graduated cylinder
hot plate	hot mitts
thermometer	stopwatch

Procedure

1. Read and complete a lab safety form.
2. Add 20 g of water to the first beaker. Add 40 g of water to the second beaker, 60 g to the third beaker, and 80 g to the last beaker.
3. Set all four beakers on top of the same hot plate. Arrange them so they are evenly spaced on the top of the hot plate.
4. Create a table in the Data and Observations section on the next page to record the temperatures of the four beakers. Measure the initial temperature of the water in each beaker. Record your data in the table.
5. Turn on the hot plate to medium-high. Leave the hot plate on for 5 min.
6. After 5 min, turn off the hot plate. Measure the final temperature of the water in each beaker. Record your data.
7. Follow your teacher's instructions for proper cleanup.



Data and Observations

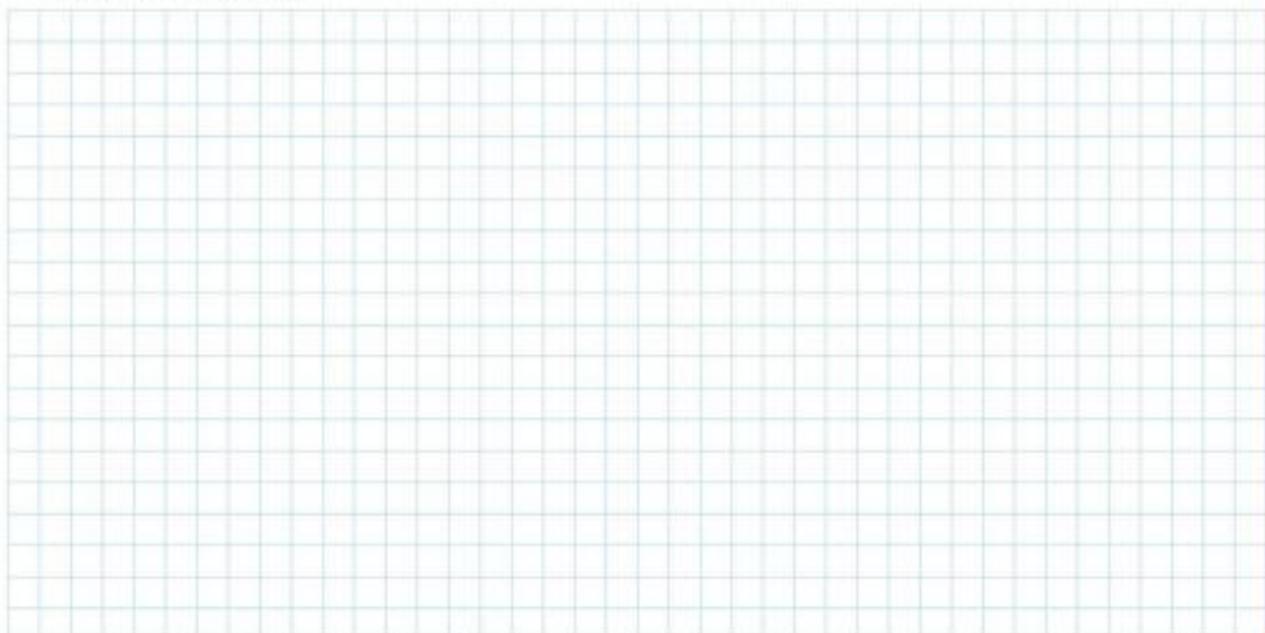
Analyze and Conclude

8. **MATH Connection** Find the change in temperature for each mass of water by subtracting the initial temperature from the final temperature.

9. What patterns do you notice in the data?

10. Plot the temperature and mass data for the beakers on the grid below.

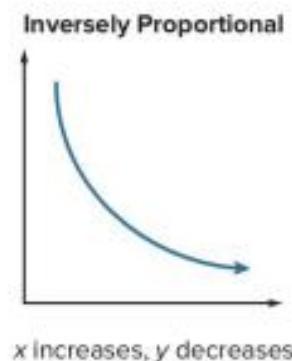
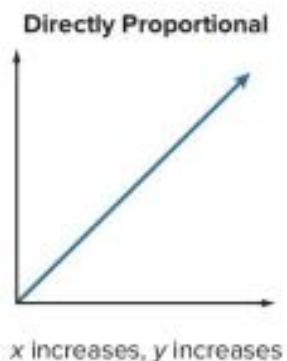
Plot the temperature change on the vertical axis and mass on the horizontal axis. Label the axes and add a title. Draw a line that goes through the points.



Analyze and Conclude, continued

11. Describe the relationship between the two variables.

Thermal Energy Transfers and Mass Recall that mass is one of the factors that determines the amount of thermal energy in a substance. It takes more energy from the surroundings to increase the kinetic energy of the particles if there are more particles. As mass increases, the change in temperature will decrease for the same energy input. This is an inversely proportional relationship. Identifying proportional relationships provides information about different properties. For instance, knowing that change in temperature v. mass is an inversely proportional relationship would help answer a problem on whether it's faster to heat up a small pot of water or a large pot of water.



THREE-DIMENSIONAL THINKING

Sketch a particle **model** to explain the relationship between change in temperature and mass.

COLLECT EVIDENCE

How does the mass of a material in the kitchenware affect how it transfers thermal energy? Record your evidence (A) in the chart at the beginning of the lesson.

How does the type of matter affect the change in temperature of a substance?

In a kitchen you will find all kinds of different materials used for baking, cooking, freezing, and other food related activities. For instance, a pan used to bake bread is made up of metal, but a hot mitt used to remove the bread from the oven is made from cotton or silicone. Does the type of material something is made from determine how thermal energy transfers? Let's find out!



LAB Melt Down

Safety



Materials

beakers (3)
hot water
aluminum foil
cotton batting
ice cubes (3)
petri dishes (3)
stopwatch
hot mitts



Procedure

1. Read and complete a lab safety form.
2. Place 75 mL of hot water in each of three beakers.
3. Place a piece of aluminum foil over the first beaker and a piece of cotton batting over the second beaker. Leave the third beaker open.
4. Place ice cubes of equal sizes in three petri dishes. Place one dish on top of each beaker. Use a stopwatch to measure the time it takes for each ice cube to melt. Record your data and observations on the next page.
5. Follow your teacher's instructions for proper cleanup.

Data and Observations

Analyze and Conclude

6. Which set-up melted the ice cube the fastest? The slowest?

7. How does your evidence on the amount of time it took the ice cubes to melt explain how much thermal energy each material transferred?



Materials and Energy Transfer In the Lab *Melt Down*, the aluminum foil, cotton batting, and the air in the room transfer thermal energy differently. If you could control all of the other variables, you could find out how much thermal energy each material transferred. In the next investigation, find out how a group of students discovered just how much energy was needed to heat water.

INVESTIGATION

Heat of Water

Read the passage. Use the information from the passage to answer the following questions.

Tama, Jason, and Sia wanted to determine how much energy was needed to heat water. To cut down on multiple trials, they all decided to use different masses of water but heat them all by 10°C . Tama found the energy needed to heat 10 g of water was 418 J. Jason found the energy needed to heat 30 g of water was 1254 J. Sia found the energy needed to heat 20 g of water was 836 J.



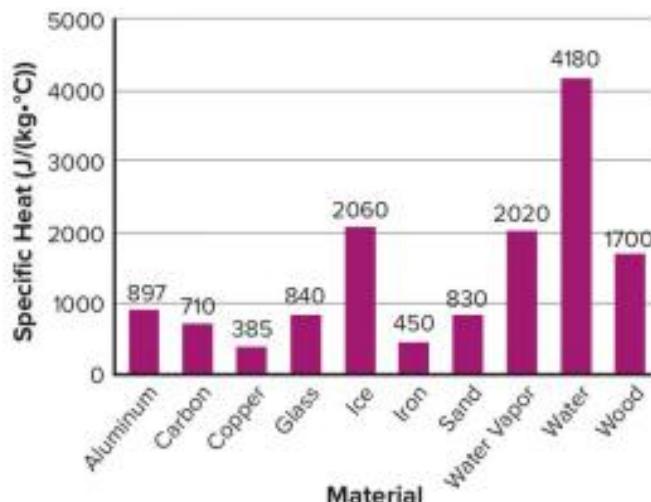
1. Organize the data into a table.

2. What patterns do you notice in the data?

3. **MATH Connection** Is there a common ratio between the data sets? Explain what you think the ratio means.

Specific Heat The ratio that you found describes the specific heat of a substance. **Specific heat** is the amount of thermal energy required to increase the temperature of 1 kg of a material by 1°C. Every material has a specific heat. It does not take much energy to change the temperature of a material with a low specific heat compared to a material with a high specific heat. The chart below lists specific heats of various materials.

Specific Heats of Common Materials



 **GO ONLINE** for additional opportunities to explore!

Want to know more about how a material affects thermal energy transfers?

Investigate how specific heat determines which materials are used for keeping us cool or warm by performing one of the following activities.

Model how energy transference is determined by types of materials in the **PhET Interactive Simulation** *Energy Forms and Change*.

OR

Argue the use of home insulation after reading the **Scientific Text** *Insulating the Home*.

EARTH SCIENCE Connection You may have noticed that the specific heat of water is particularly high. A large amount of energy is needed to increase the temperature of water by 1°C. This characteristic of water has many benefits. The high specific heat of water is one of the reasons why pools, lakes, and oceans stay cool in summer. It also means that areas of land that are near large lakes or an ocean generally have more moderate climates. They are cooler in the summer and warmer in the winter because it takes a lot of energy to change the temperature of the water.



Conductors and Insulators Materials are classified into two groups based on their specific heats: conductors and insulators. A **thermal conductor** is a material through which thermal energy flows easily. The particles in a thermal conductor move easily so kinetic energy is transferred easily between particles. Metals are better thermal conductors than nonmetals. A **thermal insulator** is a material through which thermal energy does not flow easily. The particles in a thermal insulator do not move as easily so kinetic energy is not transferred easily between particles.

The handle of the pan in the figure on the right is made out of wood. Wood is a thermal insulator. The pan is made out of iron—a thermal conductor. Thermal conductors have lower specific heats than thermal insulators. This means it takes less thermal energy to increase the temperature of a thermal conductor than it takes to increase the temperature of a thermal insulator of the same mass.



THREE-DIMENSIONAL THINKING

You can bake food in either a metal pan or oven safe glass. Which would require more **energy** to heat up? Which would cool down the fastest? Explain your reasoning.

COLLECT EVIDENCE

How does the type of material in the kitchenware affect how it transfers thermal energy? Record your evidence (B) in the chart at the beginning of the lesson.

What other properties affect thermal energy transfer?

The materials that make up a piece of matter and the mass of that matter affect how much thermal energy transfers.

Kitchenware also comes in many different shapes and colors. There are thick cast iron skillets and thin aluminum pans, tall glasses and shallow bowls. Do these factors affect how much thermal energy transfers? Let's investigate!



LAB

Tall, Thin, or Tough

Safety



Materials

beakers	water
aluminum foil	cotton batting
ice cubes	petri dishes
balance	hot plate
hot mitts	thermometer
colored paper	stopwatch
tape	



Procedure

1. Read and complete a lab safety form.
2. Return to your notes on the types of cookware from the beginning of the lesson. Predict what other properties of materials affect thermal energy transfers. In your Science Notebook, record some questions that you could investigate to find out what other properties affect thermal energy transfer.
3. Choose one question to investigate.
4. Write a set of procedures in your Science Notebook that you will use to answer your question. Include in your procedure:
 - A. The purpose of your investigation. Identify what relationship between the variables will be tested and any needed controls.
 - B. How the initial and final temperatures are going to be measured and in what units.
 - C. The mass and types of matter used in the investigation.
 - D. The evidence needed to relate the change in temperature to the property.
 - E. Needed materials and safety precautions to be taken.

5. Have your teacher approve your procedures. Follow your approved procedures to complete your investigation.
6. After you complete your investigation, follow your teacher's instructions for proper cleanup.

Data and Observations



Analyze and Conclude

7. Construct an explanation on how the evidence you collected during the lab supported or opposed the relationship between the property and the change in temperature. Are there any alternative interpretations of the evidence?

Thermal Energy and Properties of Materials Many different properties of a substance can determine how thermal energy will transfer. Some properties include the reflectivity of a substance, the thickness of a substance, and the exposed surface area.

Reflectivity v. Absorbency	Thickness	Surface Area
Reflection is when energy carried by a wave bounces off a surface. The opposite of reflection is absorption, or the transfer of energy by a wave to a medium through which it travels. The color white reflects all radiated light energy while the color black absorbs all radiated light energy.	The thickness of a substance can determine how thermal energy is transferred. The thicker a substance, the larger the distance the thermal energy has to travel. A larger thickness could increase how long a substance takes to heat up and also delay how long it takes to cool down. Thickness relates to the mass of a substance.	Surface area is the amount of exposed, outer area of a substance. Increased surface area for a given volume increases the energy transfer between the substance and the surroundings. For example, a shallow bowl has more surface area than a deep bowl. The shallow bowl will transfer more thermal energy to the surroundings.

Many factors can affect how thermal energy is transferred between substances. The amount of energy needed to change the temperature of a matter sample by a given amount depends on the type of the matter, the size of the sample, and the environment.



THREE-DIMENSIONAL THINKING

Develop an **explanation** for which student in the image gains the most thermal **energy** from the environment.



COLLECT EVIDENCE

How do other properties of the kitchenware affect how it transfers thermal energy? Record your evidence (C) in the chart at the beginning of the lesson.

A Closer Look: Heat Sinks



Engineering Connection Heat sinks are found in electronic and mechanical devices to help regulate temperature levels. Heat sinks in computers are used to cool processing units. Without a good heat sink, the device could overheat, and the high temperature could cause delicate parts of a processor to melt. Heat sinks are made of substances such as copper or aluminum. These materials are chosen because they quickly conduct thermal energy away from the source.

Heat sinks utilize additional properties of materials, such as maximizing the surface area of the heat sink in contact with a cooling medium. Many devices use air as the cooling medium. Heat sinks often include "fins" that increase the surface area. This allows the thermal energy gained by the heat sink to transfer quickly to the air. In computers, heat sinks are often paired with a fan to help transfer the excess thermal energy to the surroundings and away from the processor.



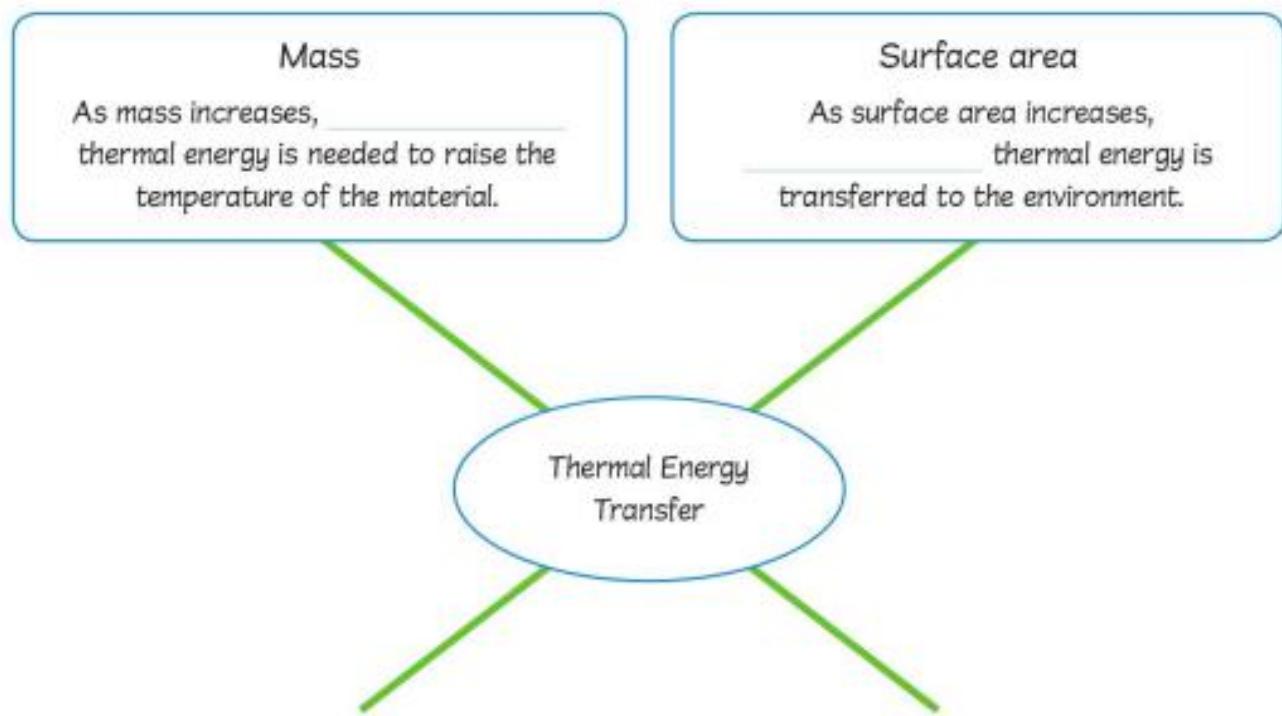
It's Your Turn

Investigate Where else are heat sinks found? Are all heat sinks made of either copper or aluminum? Research one of these questions or develop your own question to investigate on heat sinks. After you complete your research, create a short presentation to share what you found.

Review

Summarize It!

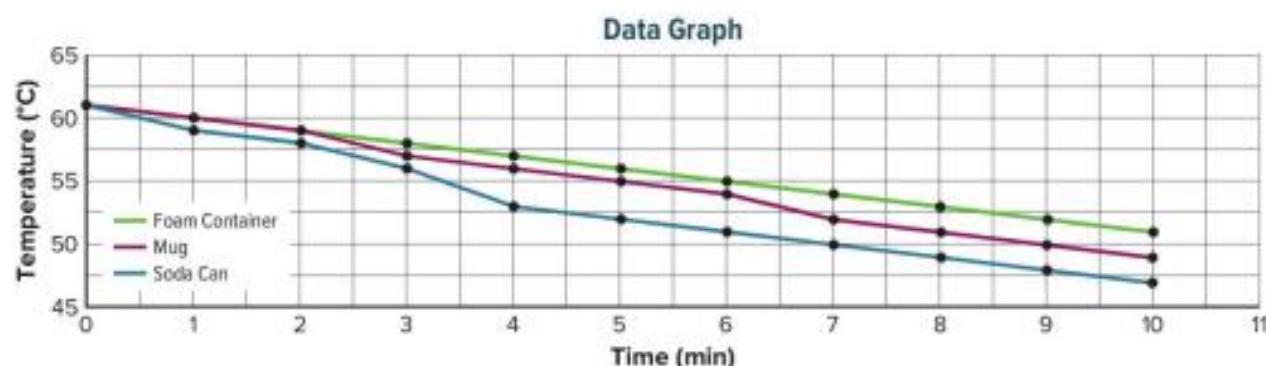
1. **Organize** Complete the graphic organizer below with the properties that affect how thermal energy transfers between materials. Add any additional properties that you discovered from the lesson.





Three-Dimensional Thinking

Jake and Sonya perform a laboratory investigation to explore thermal energy transfer between different materials. They place 100 mL of hot tap water in each of these containers: a foam cup, a mug, and an empty soda can. They record the temperature of the water every minute for 10 minutes. Finally, they plot the data on a graph.



2. Which substance is the best at conducting thermal energy?
 - A foam container
 - B mug
 - C soda can
 - D None of the above are good conductors.

3. Which variable would Jake and Sonya need to keep constant to make sure it doesn't affect how the thermal energy transferred out of the three containers?
 - A mass of water in each container
 - B open surface area of each container
 - C color of each container
 - D All of the above would need to be constants.

4. The specific heat of air is 1.0 J/g•K and the specific heat of copper is 0.4 J/g•K. Which statement describes how each material would affect the amount of thermal energy transferred?
 - A Air and copper transfer thermal energy the same.
 - B Copper transfers thermal energy the quickest.
 - C Air transfers thermal energy the quickest.
 - D Specific heat does not determine how thermal energy transfers.

Real-World Connection

5. **Argue** A kitchenware company is looking to market a new skillet. They want to be able to say that it "heats up quickly and cools down quickly". The materials they have narrowed it down to are: aluminum, copper, and glass. Develop an argument supporting or opposing the three choices based on their specific heats.

Material	Specific Heat (J/(kg·°C))
Aluminum	897
Copper	385
Glass	840

6. **Infer** why the sauce on a hot pizza burns your mouth but the crust of the pizza does not burn your mouth.

Still have questions?

Go online to check your understanding about what properties affect thermal energy transfers.

REVISIT SCIENCE PROBES

Do you still agree with the student you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that student now.

EXPLAIN THE PHENOMENON



Revisit your claim about what properties affect thermal energy transfers. Review the evidence you collected. Explain how your evidence supports your claim.

PLAN AND PRESENT

STEM Module Project

Engineering Challenge

Now that you've learned thermal energy transfers, go to your Module Project to develop a plan on how to test the new cooking technologies to see which ones meet the criteria and constraints of the problem. Keep in mind that the better the design, the larger the temperature increase of the water.





STEM Module Project

Engineering Challenge

Cookin' with the Sun

You work at an engineering design company that develops alternative cooking methods. Your clients are a group of researchers preparing for a data collection trip where they will be in the field for an extended amount of time. For the last few years, their data collection site has been under drought conditions and no open flames are allowed. They have made a request for a device that will enable them to cook without using open flames.

Your goal is to design, construct, and test a device that is capable of heating a pot of water. You will present your device along with your constructed argument about the device's effectiveness to the clients.



Planning After Lesson 1

Before you begin designing your heating device, record your thoughts about the following:

- who needs this solution
- what needs must be met
- any relevant scientific issues
- any societal or environmental impacts

Explain the importance of why all the above components must be defined.



STEM Module Project

Engineering Challenge

Planning After Lesson 1, continued

What criteria does this technology need to meet? Order the criteria from highest priority to lowest priority.

The technology your group has been requested to build cannot use an open flame. Your design must also be economical. What other constraints are you limited by?

Planning After Lesson 2

Research technologies that use solar energy to heat foods. Record the questions and answers that drive your research in the space below. Include citations for your sources.

Create a table that lists:

- each type of technology that was researched,
- how the technology heats food without using open flame, and
- the societal and environmental impacts of each technology.

Add columns to the table that identify each criteria and constraint. Use the table to evaluate the strengths and weaknesses of each technology.

Using the results of the decision matrix, make a claim on the effectiveness of each technology as a solution to the proposed problem. Support that claim with evidence and reasoning.

Compare and contrast the information gained from Lesson 1 and Lesson 2 investigations, simulations, and videos with your research. How does what you have learned so far help you with designing a new technology that will meet all of the requirements? Record your answer in your Science Notebook.



STEM Module Project

Engineering Challenge

Planning After Lesson 3

Begin designing the technology. Sketch the technology. In the sketch include the energy inputs and energy outputs of the technology, the materials that will be used, and how this technology provides the best solution to the problem by addressing the criteria and constraints of the problem.

Once a sketch has been approved by your teacher, start building the technology as a group.

Planning After Lesson 4

Identify the factors that affect the amount of thermal energy needed to change the temperature of a substance.

As a group, develop a plan on how to investigate which technology best meets the criteria and constraints. In this plan include:

- What are the dependent variables and independent variables?
- What are the controls?
- How can the variables and controls be measured?
- What units will be used to report your data?
- How will you measure success?
- How many data points are needed to support a success?

Create tables in your Science Notebook to organize the data before testing the devices created by your class.

Test the technologies created by your class.



STEM Module Project

Engineering Challenge

Analyze and Interpret Data

Identify any patterns or trends in the class data. Explain any outliers or errors that are noticeable from the data.

Explain which characteristics from the class's technologies best met the criteria and constraints of the project by identifying any similarities or differences between data and the structure of the devices.

How could the project data collected by both your group and other groups be used to improve your group's device?

Describe how the properties of the materials that were used in your technology maximized thermal energy transfer.

What are the limitations of using your technology for the proposed solution?

Engage in Argument

Construct an argument on how the developed technology did or did not demonstrate that when the kinetic energy of the object changes, energy is transferred to or from the object.

- A.** Make a claim on what causes the kinetic energy (temperature) of an object to change. Write your draft in your Science Notebook.
- B.** Support your claim with evidence.
- C.** Pair with a partner and discuss his or her evidence. Evaluate the evidence for strengths and weaknesses including determining the source of the evidence, the sufficiency of the evidence, and if the evidence is correctly interpreted. Share your feedback with your partner.
- D.** Update your evidence with any needed changes.
- E.** Construct your explanation by including reasoning to connect the evidence to the claim. Include multimedia components and visual displays to support points.



STEM Module Project

Engineering Challenge

Present Your Argument

Write your final argument here. Then present your argument to the class.

Congratulations!
You've completed the
Engineering Challenge
requirements!

Module Wrap-Up

REVISIT THE PHENOMENON

Think about everything you have learned in the module about how energy and matter interact. Construct an explanation for what makes popcorn pop.



OPEN INQUIRY

What are one or two questions you still have about the phenomenon?

Choose the question that interests you the most. Plan and conduct an investigation to answer this question.

The Water Cycle



A photograph of a person from the side, wearing a red t-shirt with a white floral or paisley pattern. They are looking towards the right side of the frame, where a display case is visible. The display case has a blue and white label that reads "Who drank my water?".

ENCOUNTER THE PHENOMENON

How might the water you drink today be the same water a dinosaur drank millions of years ago?

 **GO ONLINE**

Check out *Who drank my water?* to see this phenomenon in action.

Collaborate With a partner, brainstorm how you could be drinking the same water a dinosaur drank millions of year ago. Record or illustrate your thoughts and reasoning below.



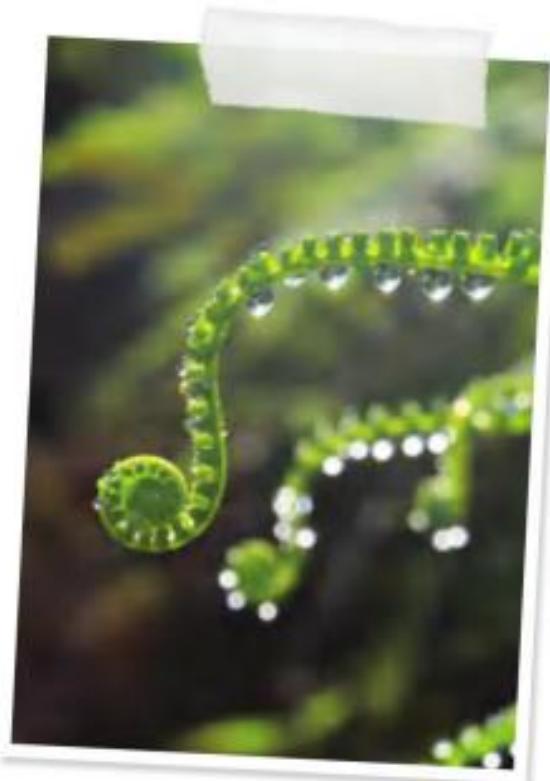
STEM Module Project Launch

Science Challenge

Dinosaurs and Dew

You have been invited to attend science camp. A goal for each camper is to take something he or she observed during the camp and model it at the Science Festival on the last day of camp.

One sunny morning while on a hike, you notice dew on a fern and wonder how it formed. The camp counselor, Mr. Twig, tells you that Earth continuously cycles its water supply. In fact, the same water you see on the fern was around during the time of the dinosaurs. He suggests you create a terrarium for your camp project to model how this could happen.



Start Thinking About It

In the image above you see water droplets collecting on a fern. Where do you think the water droplets came from? Discuss your thoughts with your group.



STEM Module Project

Planning and Completing the Science Challenge

How will you meet this goal? The concepts you will learn throughout this module will help you plan and complete the Science Challenge. Just follow the prompts at the end of each lesson!

LESSON 1 LAUNCH

What happened to the puddle?



Four friends noticed a large puddle on the sidewalk when they walked to school in the morning. When they walked home, the puddle was gone. They wondered what happened to the water that was in the puddle.

Desi: I think the water soaked into the bricks.
Trudi: I think the water went up into the clouds.
Max: I think the water is in the air around us.
Carli: I think the Sun changed it into something else.

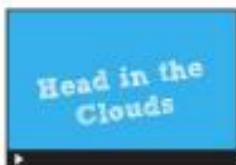
Circle the student you most agree with. Explain why you agree with that student.

Water in the Atmosphere

Cover image © McGraw-Hill Education / Michael S. Sparer/Stocktrek Images

ENCOUNTER THE PHENOMENON

Why do clouds appear and disappear?



GO ONLINE

Watch the video *Head in the Clouds* to see this phenomenon in action.

Record your observations about the phenomenon in the space provided.

Why do you think this occurs?

EXPLAIN THE PHENOMENON

Did you see how clouds form and vanish and constantly change shape? Use your observations about the phenomenon to make a claim about why clouds appear and disappear.

CLAIM

Clouds appear and disappear by...



COLLECT EVIDENCE

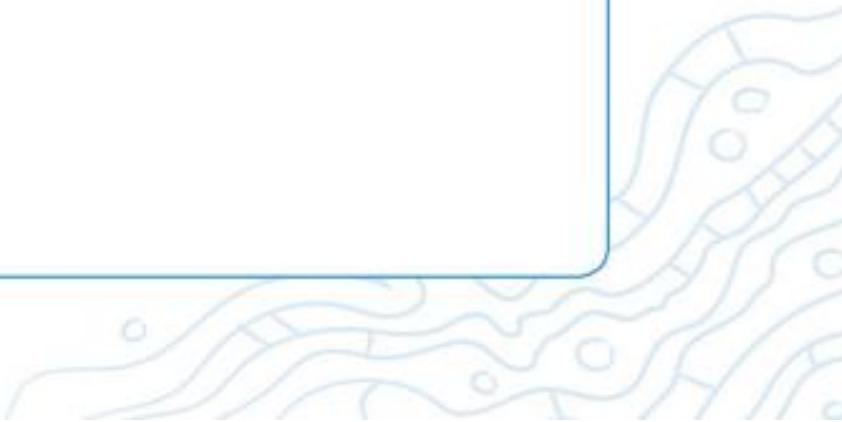
as you work through the lesson.

Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain why water in clouds "disappears?"

B. What evidence have you discovered to explain how water enters the atmosphere?



MORE EVIDENCE

C. What evidence have you discovered to explain how clouds appear?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Clouds appear and disappear by...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

Where is water on Earth?

Earth is often referred to as the blue planet because so much of its surface is covered with water. If you study a photograph of Earth taken from space, you can see that water covers much more of Earth than landmasses do. Water is also in the clouds in the atmosphere, the air around you, beneath your feet, and in you and other organisms.

The distribution of water on Earth depends on the interactions among the four subsystems of the larger Earth system. Four of these smaller subsystems are the atmosphere, the biosphere, the geosphere, and the hydrosphere.



THREE-DIMENSIONAL THINKING

With a partner, label the **subsystems** of the larger Earth system in the photo. How do you think water moves between the subsystems? Create a diagram that **models** your ideas on how water moves between Earth's subsystems in your Science Notebook.



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So how does water move from place to place? You will start your investigation with how water leaves Earth's surface and enters the atmosphere.



Want more information?

Go online to read more about how water enters and cycles through Earth's atmosphere.

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

What influences why and how quickly water “disappears?”

After a morning storm, you might notice puddles on the sidewalk. Later that afternoon, the puddles are gone. Similarly, water in clouds seemingly vanishes into thin air. What causes water to “disappear?”

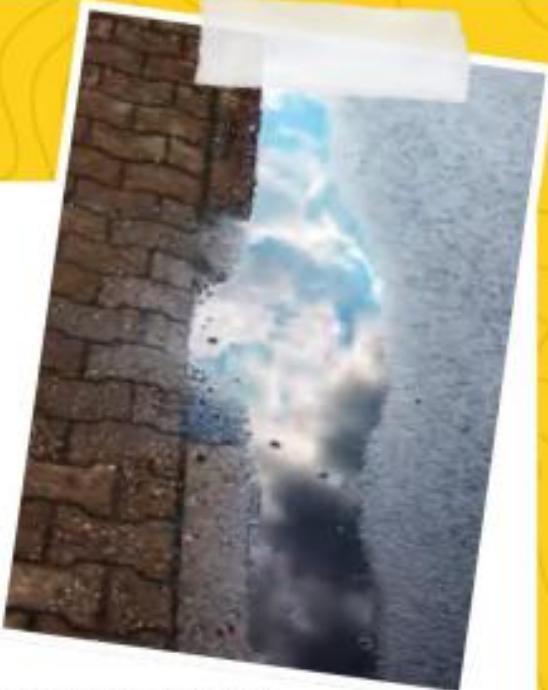
LAB Into Thin Air

Safety



Materials

square of brown paper towels (2)	light source
paper plates (2)	metric ruler
dropper	stopwatch
10 mL room-temperature water	



Procedure

1. Read and complete a lab safety form.
2. In your Science Notebook, create a list of questions about what variables might affect how quickly water “disappears.”
3. Place each piece of paper towel on a paper plate. Label one paper towel *A* and one paper towel *B*.
4. Add 1 drop of room-temperature water to each paper towel.
5. Allow the drops to spread out until they don't seem to be expanding anymore. Measure the diameter of each droplet spot. Record your measurements in the Data and Observations section on the next page.
6. Place paper towel *A* in direct sunlight or under another light source. Place paper towel *B* in the shade.
7. Measure the droplet spots every minute for five minutes. Record your observations.
8. Follow your teacher's instructions for proper cleanup.

Data and Observations

Time Elapsed (mins)	Diameter of Water Drop on Paper Towel A (mm)	Diameter of Water Drop on Paper Towel B (mm)
0		
1		
2		
3		
4		
5		

Analyze and Conclude

9. Make a claim about what affects the rate at which water “disappears.”

10. What evidence from the lab supports your claim?



PHYSICAL SCIENCE Connection Water does not actually disappear from a puddle or a cloud. It evaporates. **Evaporation** is the process by which a liquid, such as water, changes into a gas. When the Sun shines on a body of water, water near the surface absorbs thermal energy and becomes warmer. As a molecule of water absorbs energy, it begins to vibrate faster. When it has enough energy, it breaks away from other water molecules. It rises into the atmosphere as a particle of gas called water vapor. Like other gases in the atmosphere, water vapor is invisible.



THREE-DIMENSIONAL THINKING

On the figure below, **model** the process that changes liquid water to water vapor. Label the transfer of **energy** that takes place during this process.



How does **energy** from the Sun drive the cycling of **matter**?

COLLECT EVIDENCE

Why do clouds and other bodies of water "disappear?" Record your evidence (A) in the chart at the beginning of the lesson.

How else can water enter the atmosphere?

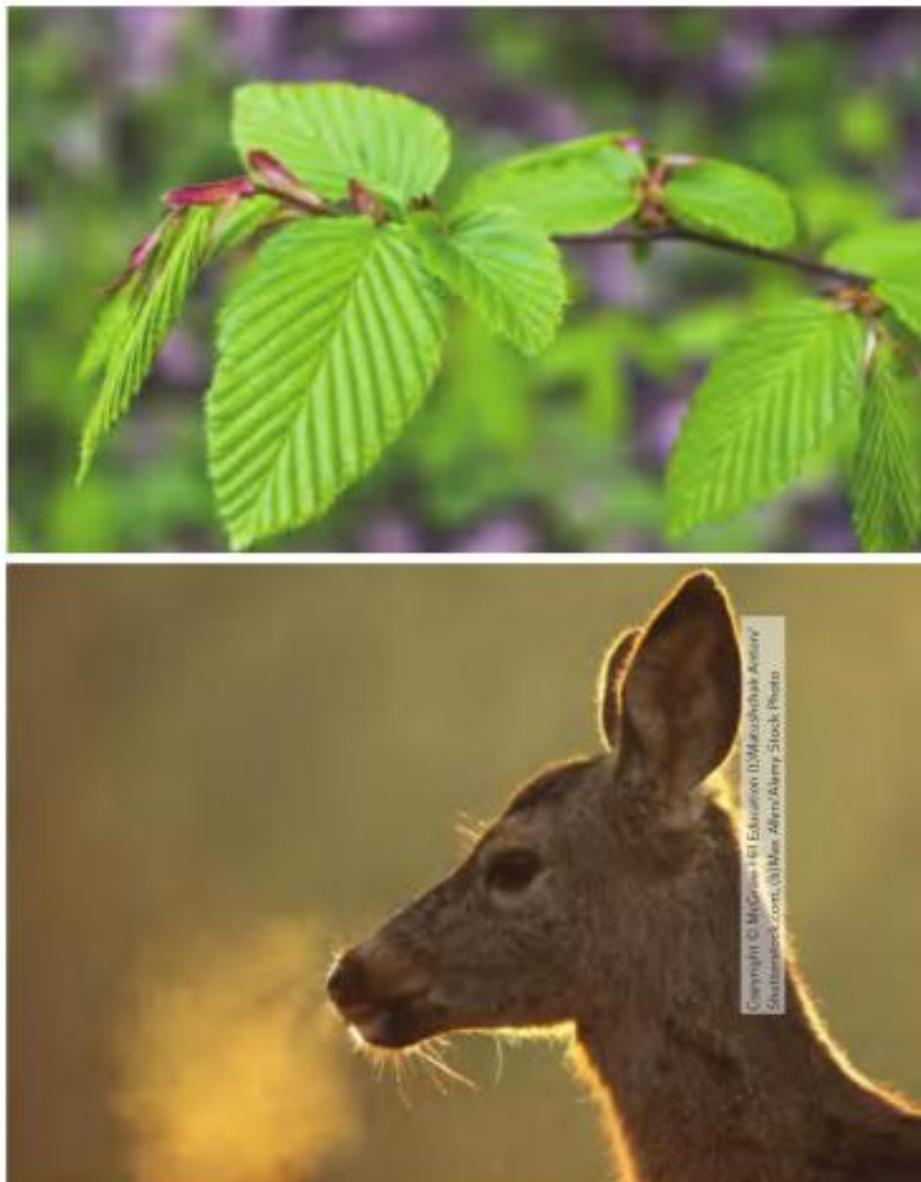
In the *Into Thin Air* lab, you learned that energy from the Sun drives evaporation on Earth's surface. Oceans hold most of Earth's water, so they are major sources of water vapor. But, water also evaporates from landforms such as rivers and lakes, or even puddles and soil. These sources, along with oceans, account for 90 percent of the water that enters the atmosphere. Where might the remaining 10 percent come from?

LIFE SCIENCE Connection

Plants and animals also contribute to the cycling of water on Earth. All living organisms rely on freshwater. In most plants, water travels from the roots up through the stems and into the leaves. When plants have an abundant water supply or experience increasing air temperatures, they release water vapor into the atmosphere. This usually occurs through the leaves. The process by which plants release water vapor into the atmosphere is called **transpiration**.

Some water vapor also comes from organisms through cellular respiration. During this process, food molecules are broken down and carbon dioxide and water are released as waste. When animals, such as this deer, breathe out, they release this carbon dioxide and water vapor from their lungs into the atmosphere. Plants also release water, as well as oxygen, through openings in their leaves.

Water is also stored in the tissues of plants and animals. This water is released back to the environment when organisms die and decompose.



COLLECT EVIDENCE

How else does water enter the atmosphere? Record your evidence (B) in the chart at the beginning of the lesson.



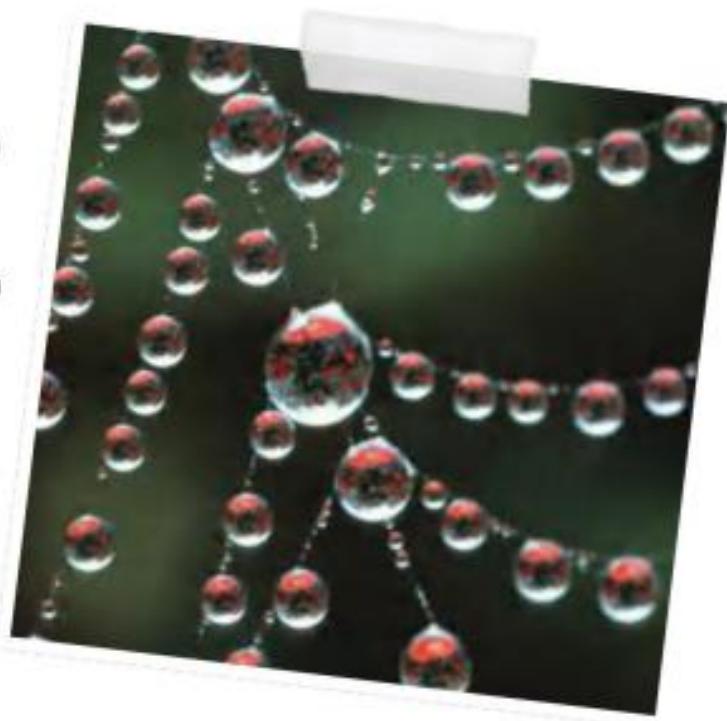
THREE-DIMENSIONAL THINKING

Model the three ways water enters the atmosphere. Use arrows and labels to show the transfer of **energy** that drives the cycling of water from Earth's surface to Earth's atmosphere.



How can you get water to "reappear?"

Now that you know that water vapor is an invisible gas in the air around you, what can you do to make it liquid water again? Think about how grass or a spider web is sometimes wet with dew in the morning, even though it did not rain the previous night. Or how water beads on the outside of a cup filled with a cold drink. In the following lab, you will use your understanding of the energy transfer involved in evaporation to reverse the process. How can you get water to "reappear?"



Safety**Materials**

beaker
ice
cold water
warm water
resealable plastic bag

Procedure

1. Read and complete a lab safety form.
2. With your team, plan an investigation using the provided materials to collect water from the air.



3. Have your teacher approve your team's plan. Carry out your investigation.
4. Evaluate if your investigation collected water vapor. If not, revise your plan and repeat steps 2–3.
5. Share your results with the class.
6. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

7. How were you able to collect water from the air?



8. What have you seen in the natural world that results from the same process?

9. Make a claim about how water vapor in the atmosphere can reappear as liquid water. What evidence from the investigation supports your claim?

 **GO ONLINE** for an additional opportunity to explore!

PHYSICAL SCIENCE Connection Want to know more about how water changes from one state to another? Then perform the following activity.

Investigate temperature changes in the **Lab** *What happens to temperature during a phase change?*

PHYSICAL SCIENCE Connection In the *Out of Thin Air* lab, you discovered that water vapor becomes liquid water as it cools. When you exhale outside on a cold winter day, you can see the water vapor in your breath condense into a foggy cloud in front of your face. This also happens when warm air containing water vapor cools as it rises in the atmosphere. Temperatures in the atmosphere near Earth decrease with increasing altitude. So, as water vapor rises through the atmosphere, it becomes cooler. Eventually it loses enough thermal energy that it returns to the liquid state.



The process by which a gas changes to a liquid is **condensation**. Water vapor condenses on small particles in the air and forms droplets. Sometimes the water droplets in the atmosphere lose so much thermal energy that tiny ice crystals form. The process by which a liquid turns into a crystalline solid is called **crystallization**. Recall that energy is absorbed during evaporation. When water changes state from a gas to a liquid, or from a liquid to a solid, energy is released.

When these small particles are surrounded by thousands of other droplets or ice crystals, they block and reflect light. This makes them visible as clouds or fog.



THREE-DIMENSIONAL THINKING

On the figure below, **model** the process that changes water vapor to liquid water. Label the transfer of **energy** that takes place during this process.



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COLLECT EVIDENCE

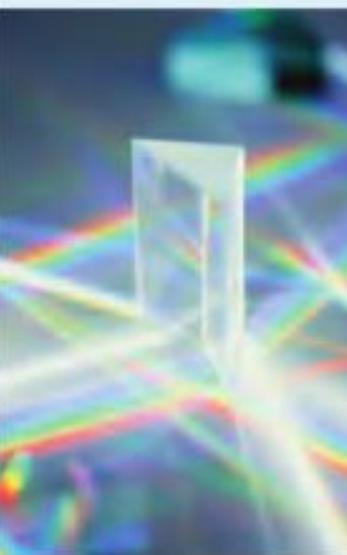
How do clouds form? Record your evidence (C) in the chart at the beginning of the lesson.

A Closer Look: Solar Halos

Have you ever noticed a circular rainbow forming around the Sun with no rain in sight? This phenomenon is called a solar—or Sun—halo. Solar halos can occur when there are high, thin cirrus clouds drifting 6,100 meters or more above our heads.

Why do these types of clouds make a halo around the Sun? Cirrus clouds are composed of millions of tiny ice crystals. At high enough altitudes in the sky, water vapor condenses and then crystallizes into ice. When light passes through the ice crystals, the light wave changes direction. The change in direction of the light wave is called refraction. The refraction of the light through the ice crystals in a solar halo enables your eyes to see all the colors of the rainbow, similar to what happens when light passes through a prism, as shown to the right.

The halo sparkles because the light also reflects off the ice crystals, just like when the Sun reflects off a car mirror. The ice crystals and the Sun have to be positioned just right for your eyes to see the halo.



It's Your Turn

Research There are three main cloud classifications, grouped according to the heights at which their bases form. Cirrus clouds, for example, are classified as high clouds. Research these groups and create a data table in your Science Notebook detailing the main cloud classifications. Include an example from each classification and illustrations or photos.

Review

Summarize It!

1. **Sketch** Create a concept sketch that models how water cycles into and through the atmosphere. To construct a concept sketch, begin by listing the processes and relationships you want to describe. Then, draw your sketch and write complete sentences describing the sketch. Include labels for the energy that drives water cycling, the state that water is in at each step (solid, liquid, or gas), and the transfer of thermal energy. Be creative!



Three-Dimensional Thinking

Jorge wanted to model two processes that cycle water in the atmosphere for a class project. He began by filling a self-sealing plastic bag half-full of water. After sealing the bag, he taped it to a sunny window. After a few hours, water beaded along the inside of the bag.

2. Which processes are represented by Jorge's model?

- A transpiration and respiration
- B condensation and crystallization
- C respiration and evaporation
- D evaporation and condensation

Examine the photo below.



3. Which statement best describes the transfer of energy in the photo above?

- A When water changes state from a liquid to a solid, thermal energy is absorbed.
- B When water changes state from a solid to a liquid, thermal energy is absorbed.
- C When water changes state from a liquid to a solid, thermal energy is released.
- D When water changes state from a solid to a liquid, thermal energy is released.

Real-World Connection

4. **Determine** one way you contribute to water in the atmosphere in your day-to-day activities. Explain why this activity is part of the cycling of water through Earth's systems.

5.  **ENGINEERING Connection** About 97 percent of Earth's water is salty. People can't drink salt water. Using what you've learned about the water cycle, explain which processes could be used to design a device for turning salt water into freshwater.



Still have questions?

Go online to check your understanding about how water cycles in Earth's atmosphere.

REVISIT



Do you still agree with the student you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that student now.

EXPLAIN THE PHENOMENON



Revisit your claim about how clouds can appear and disappear. Review the evidence you collected. Explain how your evidence supports your claim.

START PLANNING

STEM Module Project Science Challenge

Now that you've learned about how water enters and cycles through the atmosphere, go to your Module Project to begin planning your terrarium. Keep in mind that you want to explain how the dew on a fern today might be the same water that was around with the dinosaurs.



LESSON 2 LAUNCH

Groundwater



Jane was drinking a glass of water. She asked her father where the water came from. Her father said it was groundwater that was pumped up by their well. Jane wondered what the water looked like underground. This is what her family said:

Mom: I think it looks like a huge ocean underground.

Dad: I think it looks like a small lake underground.

Jack: I think it seeps into little holes or spaces between the soil and the rocks.

Annie: I think it looks like a long, underground tube filled with water.

Philip: I think it looks like an underground volcano with water spurting out of the top.

Which person do you agree with the most? Explain your ideas about groundwater.

Water on Earth's Surface

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ENCOUNTER THE PHENOMENON

How might a single drop of water travel from a cloud to a stream to an aquifer?

In this activity, you will act like a water droplet and move from one location to another as directed by your teacher. Take notes on any phase changes that you might have undergone, and the driving force behind your movements. Then, draw a map of the multiple paths you took below.



On the Move

GO ONLINE

Watch the video *On the Move* to see this phenomenon in action.

EXPLAIN THE PHENOMENON

As a water droplet, you traveled to lots of different locations. Are you starting to get some ideas about how water moves from place to place? Use the water droplet paths you mapped to make a claim about how water could move from a cloud to a stream to an aquifer.

CLAIM

Water moves from a cloud to a stream to an aquifer by...

COLLECT EVIDENCE as you work through the lesson. Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain why water falls from a cloud?

B. What evidence have you discovered to explain how water moves along Earth's surface?

MORE EVIDENCE

C. What evidence have you discovered to explain how water enters and flows within an aquifer?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Water moves from a cloud to a stream to an aquifer by...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

Why do some clouds rain?

Energy from the Sun causes water at Earth's surface to evaporate into the atmosphere. Water vapor in the air cools as it rises, then condenses or crystallizes and forms clouds. Moisture that falls from clouds to Earth's surface is **precipitation**. Liquid water falls to the ground as rain. Frozen water reaches Earth's surface as other forms of precipitation such as snow, sleet, or hail. But why do some clouds precipitate while others do not?

FOLDABLES®

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

LAB

Safety

Materials

Procedure

1. Read and complete a lab safety form.
2. Place a dry sponge in the water for two seconds and raise it out of the water.
3. Repeat step 2 until the sponge begins to "rain."
4. Follow your teacher's instructions for proper cleanup.



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[http://www. mheducation.com](http://www.mheducation.com)

Analyze and Conclude

5. Under what circumstances did the "cloud" rain?

6. Construct an explanation in your Science Notebook about the cause of precipitation. Cite evidence from the lab.

COLLECT EVIDENCE

How and why does water travel from a cloud to Earth's surface? Record your evidence (A) in the chart at the beginning of the lesson.



 Want more information?

Go online to read more about water on Earth's surface.

Read a Scientific Text

Water moves from Earth's surface to the atmosphere and back again in the **water cycle**. The amount of water on Earth does not change. However, while the amount of water within the cycle may be stable, changes in Earth's global temperature can affect how it is cycled.



CLOSE READING

Inspect

Read the passage *Climate Change: Trends & Patterns*.

Find Evidence

Reread the second paragraph. Underline the relationships among events that can be described as cause-and-effect relationships.

Make Connections

Communicate With your partner, discuss how changes in Earth's temperature impact the stability of the water cycle. Have you noticed any changes in your region?

PRIMARY SOURCE

Climate Change: Trends & Patterns

The distribution of the world's rainfall is shifting as our climate changes. Wet areas may become wetter, dry areas drier, storms more intense, leading to more chaotic weather around the world. According to the Intergovernmental Panel on Climate Change (IPCC, 2011), an increase in the average global temperature is very likely to lead to changes in precipitation and atmospheric moisture, including shifts towards more extreme precipitation during storms.

As the lower atmosphere (the troposphere) becomes warmer, evaporation rates increase, which leads to an increase in the amount of moisture circulating. When the troposphere has more moisture, more intense precipitation occurs, thus potentially triggering more flooding over land. Conversely in other areas, warmer temperatures may lead to increased drying accelerating the onset of drought.

To predict future changes in climate, scientists use very sophisticated computer models that rely on available global data to describe climate as it is today and project how it may behave in the future. ... By providing measurements of surface water fluxes, cloud/precipitation microphysics and latent heat release in the atmosphere, GPM [Global Precipitation Measurement mission] advances Earth system modeling and analysis. More accurate global precipitation estimates improve the accuracy and effectiveness of climate models and advance understanding of climate sensitivity and future climatic change.

Source: National Aeronautics and Space Administration

ENVIRONMENTAL Connection How has the rise in global temperatures impacted precipitation patterns?

Where does all the rain go?

You learned in the *Make It Rain* lab that water in the atmosphere falls to Earth as precipitation when pulled down by gravity. More than 75 percent of precipitation falls into the ocean, and the rest falls onto land. Some of this water evaporates and goes back into the atmosphere. Some flows into lakes or streams, which join together and flow back into the ocean.

You have probably seen water flow along a stream. What you can see is only part of the story. How does water flow into and out of streams? Let's investigate!



INVESTIGATION

Streaming By

1. Observe the demonstration. Record your observations below.



2. When it first started to rain on the stream table, where did all of the water go?

3. What force caused the water to move in the way that it did?

4. What had to happen for the water to begin to flow?

5. Once the rain stopped, why did the water keep draining from the stream table?

6. What do you think the plastic tub that the water eventually flowed into represents?

7. What claim can you make about two sources of water in a stream? Use evidence from the activity to support your claim.

COLLECT EVIDENCE

Why does water on Earth's surface flow and where does it go?

Record your evidence (B) in the chart at the beginning of the lesson.

A Day in the Life of a Yuba River Waterkeeper



Many people work together to protect and preserve the Yuba River. One important role is that of a waterkeeper. Waterkeepers work with the public and government officials to ensure that future generations have a healthy river to enjoy.

One of the most important tasks for a waterkeeper is water-quality monitoring. Waterkeepers test water temperature, oxygen content, and pollutants. One test uses a black and white disk called a Secchi disk to measure turbidity, or how clear the water is. The disk is attached to a rope and lowered into the river. The deeper it can be lowered and remain visible, the less sediment the water likely contains.

On any given day, a waterkeeper can be a detective, a teacher, an ambassador, or a scientist. The keepers of the Yuba River monitor its health, identify and solve water quality problems, and educate the public about the importance of clean water.



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It's Your Turn

ENVIRONMENTAL Connection Imagine you are a waterkeeper for a river near your home or school. Investigate the quality of the water and what types of plants and wildlife depend on the river. Create a short presentation for a group of younger students to teach them the importance of protecting California's rivers.

Where is water stored?

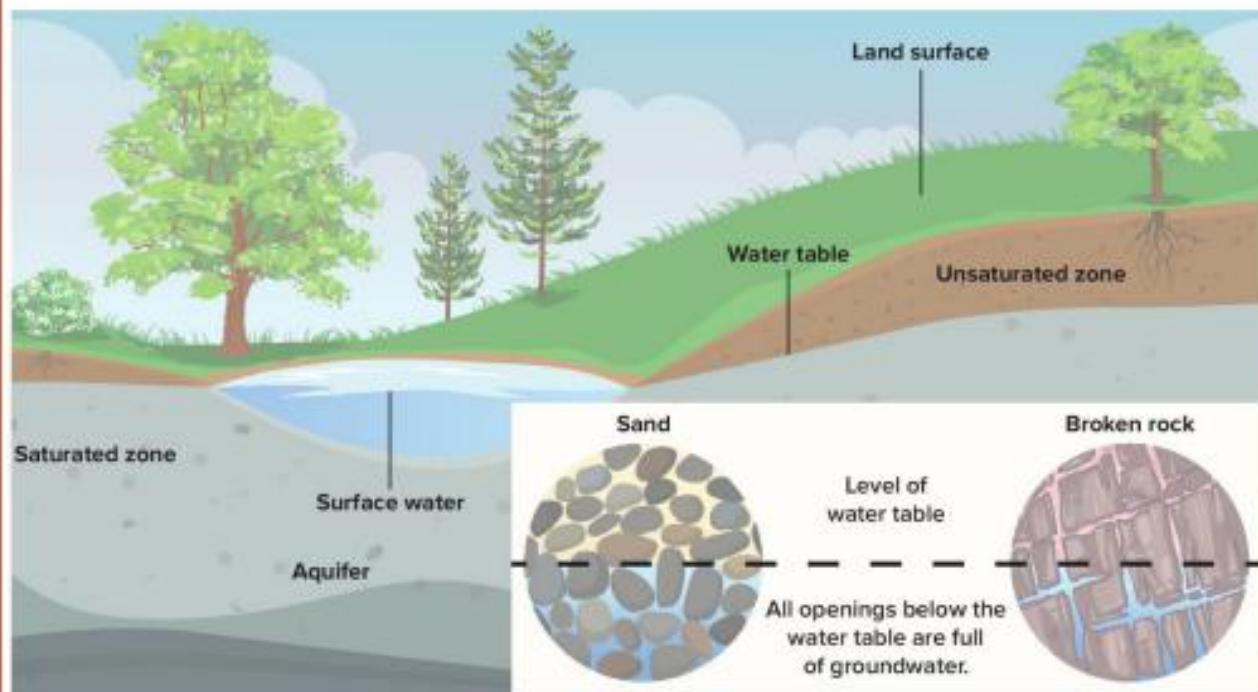
You discovered in the *Streaming By* investigation that gravity acts on precipitation, causing water on and below Earth's surface to continuously flow downhill toward the ocean. Although water is constantly moving through the water cycle, most water remains in certain storage areas for relatively long periods of time. A storage area is called a reservoir. Reservoirs can be oceans, lakes, glaciers and ice caps, and groundwater.

Water Under Your Feet Generally, water that lies below ground is called groundwater. There is an immense amount of water below our feet in **aquifers**—areas of permeable sediment or rock that hold significant amounts of water. As you observed in *Streaming By*, water seeps through soil and into tiny pores, or spaces, between sediment and rock. How do you think water moves underground?



THREE-DIMENSIONAL THINKING

1. Draw arrows on the figure below to **model** how you think groundwater might flow.



2. Read the first paragraph on the following page and revise your arrows as needed.
3. What force **causes** groundwater to flow?

Groundwater Flow Groundwater flows from higher elevations to lower elevations, and ultimately to the ocean. In some areas, groundwater is very close to the surface and keeps the soil wet. In other areas, especially deserts and other dry climates, groundwater is hundreds of meters below the surface.

LIFE SCIENCE Connection Oases—fertile lands in the desert—are usually formed when underground water gets close to the surface. When this happens, springs turn a normally arid place into an area where plants can thrive. In low-lying areas at Earth's surface, groundwater might eventually seep out of the ground and into a stream, a lake, or a wetland. In this way, groundwater can become surface water. Likewise, surface water can seep into the ground and become groundwater. This is how groundwater is replenished.



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COLLECT EVIDENCE

How does water become groundwater and where else is water stored? Record your evidence (C) in the chart at the beginning of the lesson.



GO ONLINE for additional opportunities to explore!

ENVIRONMENTAL Connection To learn more about how humans rely on and affect water resources, perform one of the following activities.

Model the behavior of groundwater in the **Lab How does pollution impact the water cycle?**

OR

Argue the issue of water diversion in the **STEM Activity Freshwater Transportation Debate**.

Water in Glaciers and Ice Sheets Water can also crystallize and collect in solid masses of ice, such as glaciers and ice sheets. Why does this occur? And what happens to glaciers after they form?

INVESTIGATION

Rivers of Ice

 **GO ONLINE** to explore the PhET Interactive Simulation *Glaciers*.

Explore the simulation on your own. When you are finished, reset the simulation and follow the instructions below.

1. Increase the average snowfall to 1.3 m. What effects does this have on the glacier?

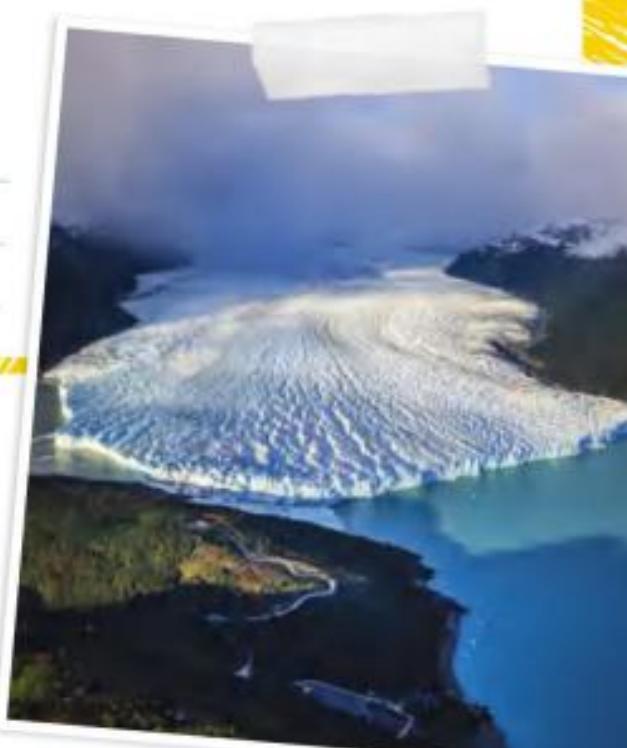


2. Decrease the average snowfall to 1 m. What effects does this have on the glacier?

3. Explain the force behind the flow of glaciers. What causes them to flow downhill?

Copyright © McGraw-Hill Education. 01/PhET Interactive Simulations. 02/University of Colorado Boulder/https://phet.colorado.edu/en. 03/Barcroft Media/Blend Images.

PHYSICAL SCIENCE Connection Imagine what happens when snow falls but doesn't melt. Year after year, layers of snow pile up. The weight and pressure of the snow above compresses the snow on the bottom into ice. Over time, the mass of ice and snow becomes so great that gravity causes it to flow downhill like a slow-moving river of ice. For most glaciers this process takes over one hundred years.



Review

Summarize It!

1. **Organize** Create a graphic organizer that illustrates the role of gravity in keeping water moving on Earth. Include at least four places where water is stored and the state that water is in at each reservoir.



Three-Dimensional Thinking

Four friends are walking along the bank of a stream. They each have differing opinions of why the stream moves along Earth's surface.



2. Which person do you agree with the most?
 - A Marco: Wind drags water particles along in the stream.
 - B Selma: Gravity causes water in the stream to move downhill.
 - C Brock: The Sun warms the stream causing it to flow.
 - D Chen: The stream moves because of its velocity.

3. Which pathway of processes would explain how a water molecule from the stream could end up in an ice sheet?
 - A evaporation, transpiration, condensation, crystallization
 - B evaporation, crystallization, precipitation, condensation
 - C evaporation, respiration, crystallization, transpiration
 - D evaporation, condensation, crystallization, precipitation

Real-World Connection

4. **Debate** Support or refute the following claim: Water on Earth will run out in our lifetime.

5. **ENVIRONMENTAL Connection** Using the concepts you learned in this lesson, why do you think it is important to focus on preventing water pollution before it happens?



Still have questions?

Go online to check your understanding about the cycling of water on Earth's surface.

REVISIT



Do you still agree with the statement you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that statement now.

EXPLAIN THE PHENOMENON



Revisit your claim about how water can move from a cloud to a stream to an aquifer. Review the evidence you collected. Explain how your evidence supports your claim.

PLAN AND PRESENT

STEM Module Project Science Challenge

Now that you've learned about how water moves on Earth, go back to your Module Project to continue planning your terrarium, build your model, and give your presentation. Your goal is to explain how the dew on a fern today might be the same water that was around with dinosaurs.





STEM Module Project

Science Challenge

Dinosaurs and Dew

You have been invited to attend science camp. A goal for each camper is to take something he or she observed during the camp and model it at the Science Festival on the last day of camp.

One sunny morning while on a hike, you notice dew on a fern and wonder how it formed. The camp counselor, Mr. Twig, tells you that Earth continuously cycles its water supply. In fact, the same water you see on the fern was around during the time of the dinosaurs. He suggests you create a terrarium for your camp project to model how this could happen.



Planning After Lesson 1

What parts in your terrarium will represent Earth's systems?

In your Science Notebook, describe how your terrarium will model how water changes state.

Planning After Lesson 2

How will your terrarium model the factors that drive the water cycle?

How will you make sure that water does not escape the terrarium? Why is this important?

List the materials you may need to build your terrarium in your Science Notebook.



STEM Module Project

Science Challenge

Develop Your Model

Look at the planning you did after each lesson. Use that information to construct your terrarium and prepare your presentation for the Science Festival.

Sketch your model in the space below. Once your terrarium is complete, make and record observations of the cycling of water on your sketch. Include labels for the water cycle processes and phase changes, and arrows for the movement of water on your sketch.

Evaluate Your Model

After completing your terrarium, identify the model elements in the table below.

Model Elements	Descriptions
Components (What are the different parts of my model?)	
Relationships (How do the components of my model interact?)	
Connections (How does my model help me understand the phenomenon?)	



STEM Module Project

Science Challenge

Create Your Presentation

Analyze your model before you make your presentation at the Science Festival on the last day of camp.

How does your terrarium help explain how the dew on a fern might be the same water that was around during the time of the dinosaurs?

What were some limitations of your terrarium? Were there any components or processes that you weren't able to include or model in your terrarium? Be sure to mention these in your presentation.

Besides your terrarium, what other visual aids or multimedia elements could you include in your presentation?

Decide how you will present your model to other campers at the Science Festival. Give your presentation.

Congratulations!
You've completed the
Science Challenge
requirements!

Module Wrap-Up

REVISIT THE PHENOMENON

Using the model you developed for the Science Challenge, explain how millions of years ago, a dinosaur might have drank the same water you drink today.

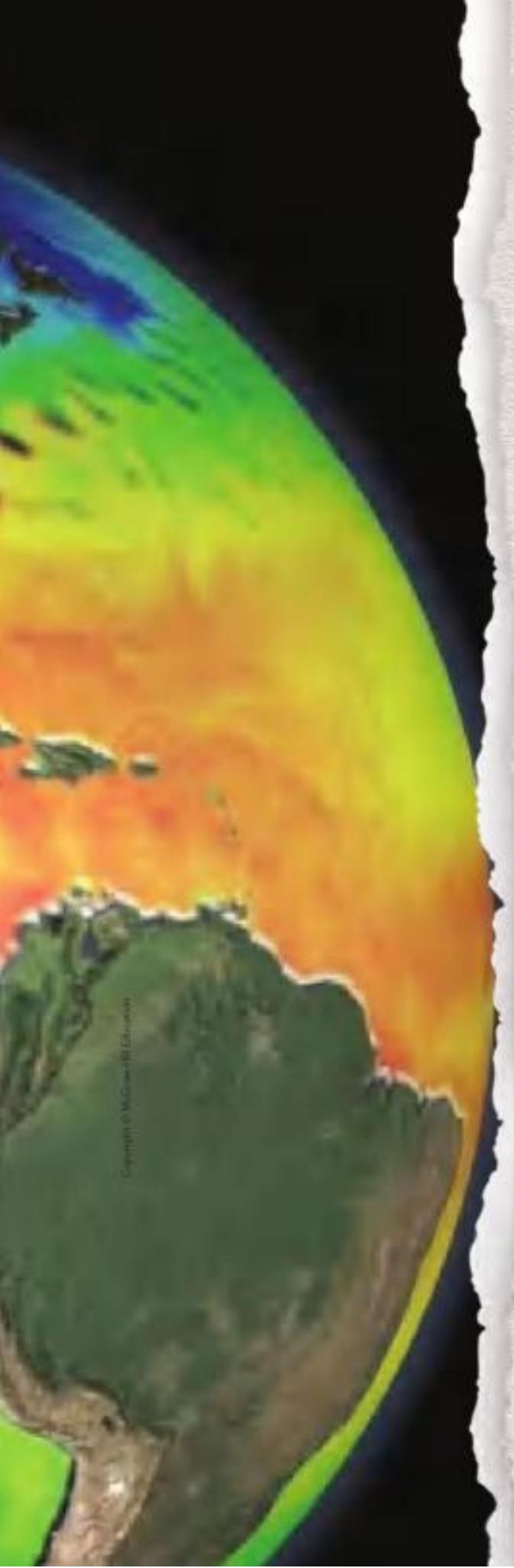


OPEN INQUIRY

If you had to ask one question about what you studied, what would it be?

Plan and conduct an investigation to answer this question.

Weather and Climate



ENCOUNTER THE PHENOMENON

How does water transfer heat around the globe?



GO ONLINE

Watch the video *Global Patterns of Circulation* to see this phenomenon in action.

Collaborate The image here shows heat along the ocean's surface. Reds, oranges, and yellows indicate warm temperatures. Blues and greens represent cooler temperatures. With your class, discuss the patterns you see in the image and video. How might these patterns affect weather and climate around the world? Record your thoughts below.

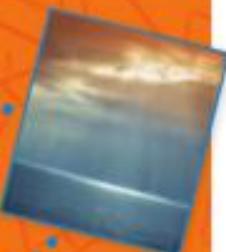


STEM Module Project Launch

Science Challenge

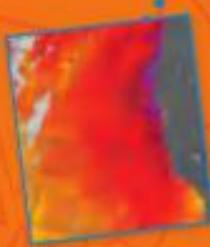
Lesson 1

Solar Energy on Earth



Lesson 2

Atmospheric and Oceanic Circulation



Lesson 3

Weather Patterns



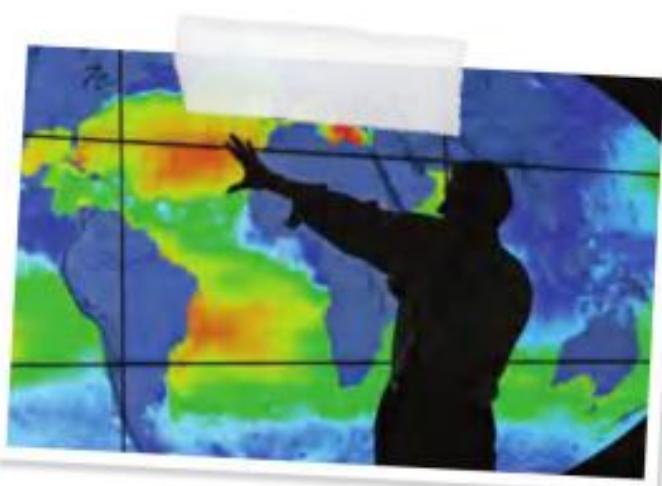
Lesson 4

Climates of Earth



As the Water Churns

You are a climatologist for the National Oceanic and Atmospheric Administration (NOAA). Your agency works with educators to help students understand weather and climate. You have been asked to develop a model for middle-school students to explain how patterns of atmospheric and oceanic circulation determine regional climates.



You will use your model to describe how the unequal heating and rotation of Earth cause the movement of air and water, and how these movements transfer thermal energy around the globe, ultimately affecting weather and climate.

Start Thinking About It

What examples of models have you used in the past? Discuss these with your group.



STEM Module Project

Planning and Completing the Science Challenge

How will you meet this goal? The concepts you will learn throughout this module will help you plan and complete the Science Challenge. Just follow the prompts at the end of each lesson!

LESSON 1 LAUNCH

What a difference!



Four friends are at the beach on a sunny day. They notice that the sand is much warmer than the ocean water. They wondered why the temperatures of these surfaces differed even though they are exposed to the same amount of sunlight.

Carla: I think that land warms faster than the ocean because water requires more energy to be heated.

Ethan: I think the land warms faster than the ocean because solar energy is more attracted to solid surfaces than liquid surfaces.

Max: I think the land warms faster than the ocean because water is clear and sunlight can pass through it more easily than the land.

Talia: I think the land warms faster than the ocean because water depth increases away from the shore.

Circle the name of the friend you most agree with. Explain why you agree with that friend.

Solar Energy on Earth

ENCOUNTER THE PHENOMENON

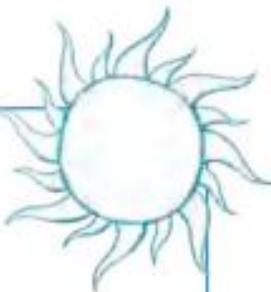
What effect does the Sun have on water?

Two containers, one black and one white, were filled with room temperature water. A lid, the same color as its respective container, was placed on top. Both containers were placed in the Sun. The water temperature of each container was measured after 20 minutes.

Analyze the data that resulted as each container was exposed to the Sun.

Water Temperature	Black Container	White Container
Temperature before sunlight exposure	25°C	25°C
Temperature after sunlight exposure	32°C	28°C

What reasoning can you provide that energy from the Sun reached the containers?



Why do you think the containers were different temperatures after exposure to the sunlight?



GO ONLINE

Watch the video *Crepuscular Rays* to see this phenomenon in action.

EXPLAIN THE PHENOMENON

You just analyzed data that resulted from two containers of water being exposed to energy from the Sun. Use the data to make a claim about how energy from the Sun warms Earth and the atmosphere.

CLAIM

Energy from the Sun warms Earth by...

COLLECT EVIDENCE

as you work through the lesson.
Then return to these pages to record your evidence.

EVIDENCE

- A. What evidence have you discovered to describe how energy from the Sun reaches Earth?

- B. What evidence have you discovered to describe if the temperature of the containers would vary depending on their locations?

- C. What evidence have you discovered to explain what would happen if the containers were filled with sand instead of water?

MORE EVIDENCE

D. What evidence have you discovered to explain how conduction helped warm the water in the containers?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

E. What evidence have you discovered to explain how color affects how solar energy is absorbed?

REVISED CLAIM

Energy from the Sun warms Earth by...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

How does energy from the Sun reach Earth?

In the beginning of this lesson, you investigated how energy from the Sun could warm an object. How does energy transfer between objects? Let's investigate!

INVESTIGATION

Catching Some Rays

1. Watch as your teacher performs the demonstration. Record your observations in the space below.



2. Describe the direction in which energy was transferred between the systems.

3. What evidence can you provide that energy from the light reached the bowl?

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Want more information?

Go online to read more about how solar energy reaches Earth's surface and the atmosphere.

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.



THREE-DIMENSIONAL THINKING

Models can be used to represent **systems** and their interactions. How did this demonstration **model** energy transfer between the Sun and Earth? Support your reasoning with a real-life example.

PHYSICAL SCIENCE Connection Energy from the

Sun reaches Earth through the process of radiation.

Radiation is the transfer of thermal energy by electromagnetic waves. All matter, including the Sun, fire, and even ice, transfers thermal energy by radiation.

Thermal energy always moves from areas of higher temperature to areas of lower temperature. The transfer of energy by radiation does not require a medium. That means the energy can travel through the vacuum of space. Radiation is the only way thermal energy can travel from the Sun to Earth.



You can feel the transfer of thermal energy by radiation when you place your hands near a fire.

COLLECT EVIDENCE

Describe how and why energy from the Sun reached the containers. Record your evidence (A) in the chart at the beginning of the lesson.

Why is Earth warmer at the equator and colder at the poles?

You learned in the previous activity that the Sun's energy warms Earth by radiation. However, the same amount of energy does not reach all parts of Earth's surface. The temperatures between the poles and the equator can vary significantly. Let's investigate what causes these temperature differences.

LAB

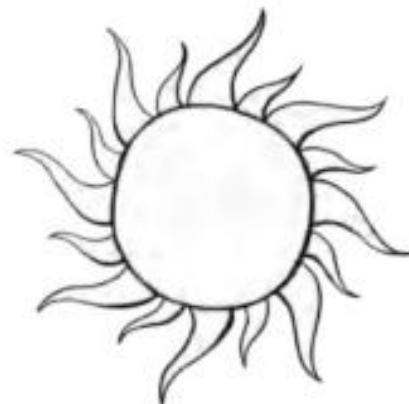
Shine On

Materials

balloon	marker
metric ruler	flashlight

Procedure

1. Read and complete a lab safety form.
2. Inflate a spherical balloon and tie the balloon closed.
3. Using a marker, draw a line around the balloon to represent the equator.
4. Using a ruler, place a lit flashlight about 8 cm from the balloon so the flashlight beam strikes the equator straight on.
5. Using the marker, trace around the light projected onto the balloon. Record what you see in the space below. Label your illustration *Equator*.
6. Have someone raise the flashlight vertically 5–8 cm without changing the direction that the flashlight is pointed. Do not change the position of the balloon. Trace around the light projected onto the balloon again. Record your observations in the space below. Label your illustration *Poles*.



7. Follow your teacher's instructions for proper cleanup.

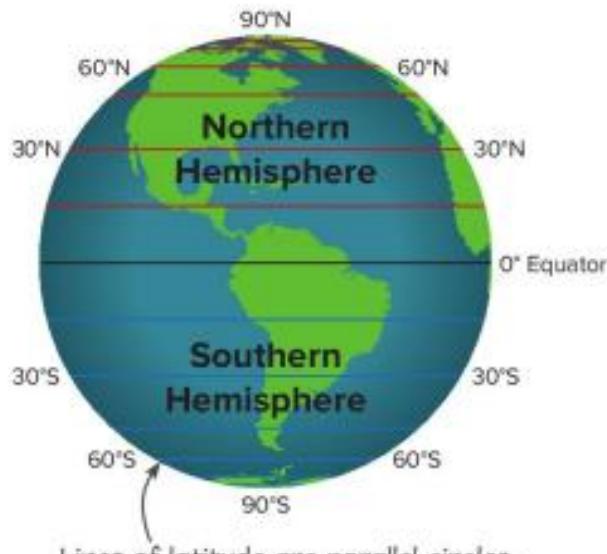
Analyze and Conclude

8. Make a claim about how the shape of Earth affects incoming solar radiation.

9. What evidence from the investigation supports your claim?

10. Use your model to explain why Earth is warmer near the equator and colder near the poles.

Solar Energy Distribution The angle of incoming sunlight depends largely on latitude. **Latitude** is the distance in degrees north or south of the equator. In latitudes near the equator—an area referred to as the tropics—sunlight strikes Earth's surface at a nearly 90° angle year-round. As a result, there is more sunlight per unit of surface area and the tropics are warmer than other areas on Earth. At latitudes near the North Pole and the South Pole, sunlight strikes Earth's surface at a low angle. Sunlight is now spread over a larger surface area than in the tropics. As a result, the poles receive very little energy per unit of surface area and are cooler.



COLLECT EVIDENCE

Would the temperatures of the containers in the opening activity vary depending on where they were placed on Earth? Record your evidence (B) in the chart at the beginning of the lesson.

What happens to solar energy on Earth?

You just learned that Earth's shape affects incoming solar radiation. Along with a spherical shape, Earth also has many different types of surfaces. Do different surface types affect how solar energy is received? Let's investigate how sand and water compare in their abilities to absorb and release heat.

LAB Warm Up and Cool Down

Safety



Materials

water	thermometer
lamp	beaker
sand	stopwatch
metric ruler	



Procedure

1. Read and complete a lab safety form.
2. Which surface, sand or water, do you think absorbs thermal energy more quickly? Which surface, sand or water, do you think releases thermal energy faster? Record your predictions below.

3. Fill a beaker halfway with sand.
4. Push the bulb of the thermometer about 2 cm deep into the sand. Keep the bulb under the sand for 1 minute. Record the temperature in the *Temperature Before Heating* column of the data table on the next page.
5. Remove the thermometer and place the beaker under the lamp. Record the temperature of the sand after 10 minutes by placing the bulb of the thermometer about 2 cm deep into the sand. Record this temperature in the *Temperature After Heating* column of the data table.
6. Remove the beaker from the light source. After 10 minutes, record the temperature of the sand in the *Temperature After Removal from Heat Source* column of the data table.

7. Repeat steps 3–6 with water.
8. Follow your teacher's instructions for proper cleanup.

Data and Observations

Type of Surface	Temperature Before Heating (°C)	Temperature After Heating (°C)	Temperature After Removal from Heat Source (°C)
Sand			
Water			

Analyze and Conclude

9. Compare the rates at which the sand and the water absorbed and released thermal energy.

10. Provide evidence to confirm or refute your predictions from Step 2.

Rate of Absorption How an area absorbs and releases thermal energy from the Sun varies depending on its physical characteristics. For example, as you observed in the lab, water absorbs and releases thermal energy more slowly than land. This is because water has a high specific heat. Specific heat is the amount of heat needed to raise the temperature of 1 kg of a material by 1°C. The specific heat of water is about six times higher than the specific heat of land. Land absorbs and releases thermal energy relatively quickly compared to water.

COLLECT EVIDENCE

How would the experiment performed in the opening activity vary if the containers were filled with sand rather than water? Record your evidence (C) in the chart at the beginning of the lesson.

How do surfaces on Earth affect the atmosphere?

In the previous activity you learned that land absorbs and releases thermal energy faster than water. Do these surfaces have any influence on the temperature of the air above them? Let's investigate if land or water influences the temperature of air.

LAB Hot Air

Safety



Materials

metric ruler	beaker
lamp	stopwatch
sand	thermometer
water	

Procedure

1. Read and complete a lab safety form.
2. Fill a beaker halfway with sand.



3. Hold a thermometer bulb 3 cm above the sand for one minute. Record the temperature in the data table below.
4. Place the beaker under the light source. Record the temperature of the air above the sand after 10 minutes keeping the same distance above the substance as before. Record the temperature in the data table.
5. Remove the light source. After 10 minutes, record the temperature of the air above the sand (same distance above the substance as before). Record the temperature in the data table.
6. Repeat steps 2–5 with water.
7. Follow your teacher's instructions for proper cleanup.



Data and Observations

Surface	Original Air Temperature Reading Above Surface (°C)	Air Temperature Above Surface After Heat is Applied (°C)	Air Temperature Above Surface After Being Removed From Heat (°C)
Sand			
Water			

Analyze and Conclude

8. Compare the rates at which the air over the sand and the air over the water absorbed and released thermal energy.

Analyze and Conclude, continued

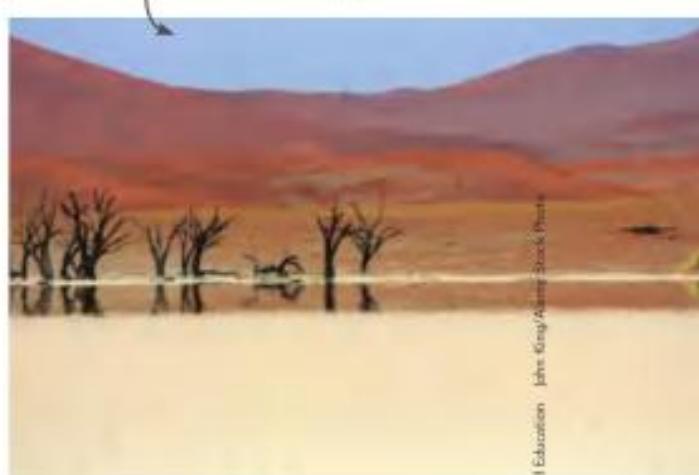
9. How did this model represent Earth's subsystems and the interactions among those systems?

Conduction The radiation absorbed by land and water on Earth is re-radiated, or transferred back, into the atmosphere. Air has a lower specific heat than both water and land. Therefore, it absorbs and releases thermal energy faster than both land and water. The temperature of air is highly influenced by the land or water below it. Air can be warmed or cooled by being in contact with land or the ocean.

PHYSICAL SCIENCE Connection When particles with different kinetic energies collide, the particles with higher kinetic energy transfer energy to particles with lower kinetic energy. The transfer of thermal energy between materials by the collisions of particles is called **conduction**. Conduction continues until the thermal energy of all particles in contact is equal. Conduction occurs in solids, liquids, and gases.

Conduction occurs where the atmosphere comes in contact with Earth; it affects only the bottom part of the atmosphere. Thermal energy always moves from an object with a higher temperature to an object with a lower temperature. So during conduction, the energy moves from the warm ground or water to the cooler air.

Conduction warms the layer of air just above the ground. When light moves through that layer it changes direction. This produces a phenomenon called a mirage.



COLLECT EVIDENCE

What role did conduction play in warming the water in the containers in the opening activity? Record your evidence (D) in the chart at the beginning of the lesson.



THREE-DIMENSIONAL THINKING

You just investigated how thermal energy from land and water influence the atmosphere. Now, use these **cause-and-effect** relationships to predict how land, water, and air will absorb and release thermal energy in the following scenarios.



1. Suppose you go to the beach in the morning of a sunny summer day. **Explain** the rate at which thermal **energy** is absorbed by the water, sand, and air during the day.

2. **Explain** why the flow of **energy** between air and sand is different than that between air and water as thermal energy is absorbed from day to night.

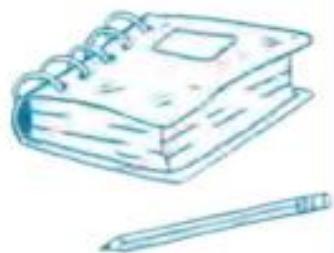
Three-Dimensional Thinking, continued



3. As the Sun begins to set, predict the **effect** on the rate at which the air, water, and sand will cool.

4. **Explain** why the flow of **energy** between air and sand is different than that between air and water as thermal energy is released.

5. In your Science Notebook, develop a **model** that shows the rate at which air, water, and land absorb thermal **energy** from the Sun. In your diagram, include the process by which thermal energy is transferred in each instance. Explain how you would change this diagram to show the rate at which air, water, and land release thermal energy.



How does the color of a surface affect how solar energy is absorbed?

As you've learned in this lesson, land, water, and air can absorb and release solar energy. There are many surface types on Earth. The reflectiveness of a surface affects the amount of solar energy that is absorbed. Let's investigate if the color of a surface affects how it absorbs, or reflects, solar energy.

LAB To Absorb, or Not to Absorb

Safety



Materials

black paper

white paper

thermometers (2)

lamp

metric ruler

stopwatch

colored pencils



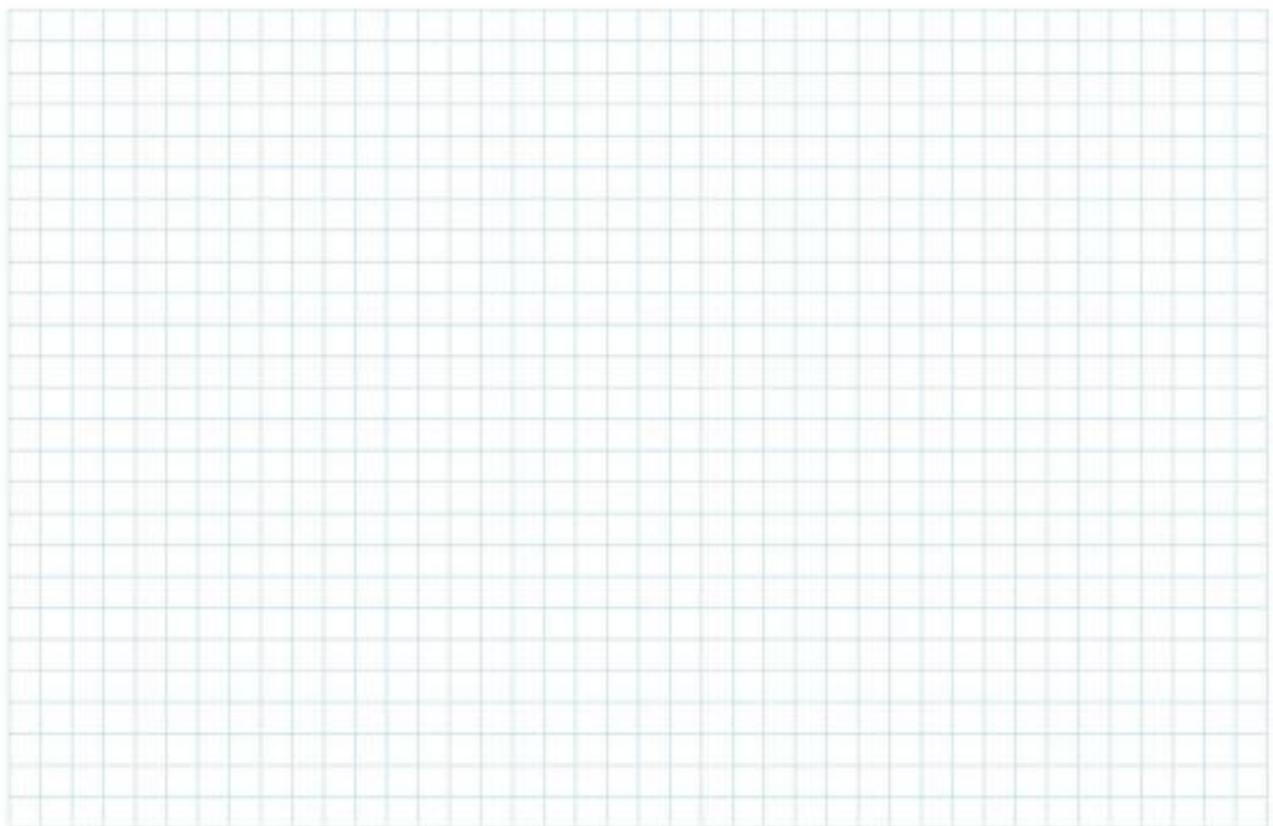
Procedure

1. Read and complete a lab safety form.
2. Lay a sheet of black paper and a sheet of white paper next to each other.
3. Lay one thermometer on each sheet of paper, placing the bulbs on the paper.
4. Create a data table in the Data and Observations section on the next page to record the temperature of each thermometer before turning on the lamp and then once per minute for 5 minutes.
5. Record the temperature for each sheet of paper.
6. Position the desk lamp 20 cm above the thermometers. The lamp should be equidistant from each thermometer bulb. Turn on the lamp. Record the temperature of each thermometer every minute for 5 minutes.
7. Follow your teacher's instructions for proper cleanup.

Data and Observations

Analyze and Conclude

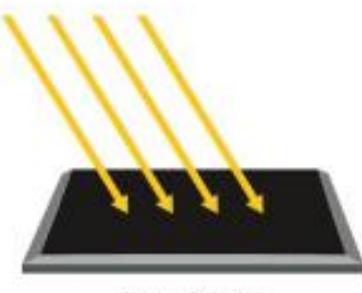
8. Plot how the temperature for each paper type changed on the grid below. Plot temperature on the vertical axis and time on the horizontal axis. Use two colored pencils to differentiate your results. Label each axis and give your graph a title.



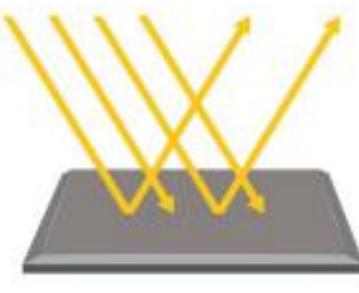
9. Explain why you think the temperature readings differed.

Albedo and Temperature The measure of the reflectivity of a surface is termed **albedo**. Light-colored, reflective surfaces like ice and thick cloud cover have a high albedo because these features reflect more sunlight. In contrast, dark surfaces such as soil or water in the absence of cloud cover have low albedo levels because they do not reflect much sunlight.

LIGHT



Low albedo



High albedo

The temperature of the atmosphere is greatly affected by the albedo of the hydrosphere, geosphere, and biosphere. The more reflective a surface is, the less it absorbs solar energy.

LIFE SCIENCE Connection Some solar energy is absorbed by living things such as plants. Plants convert sunlight into usable chemical energy in the form of sugars.



GO ONLINE for additional opportunities to explore!

Want to learn more about albedo? Then perform one of the following activities.

Read about how reflectivity is an important factor in determining the temperature at different locations on Earth in the **Scientific Text Albedo**.

OR

Survey an area around your home to explore how human activity can change the albedo of areas in the **Investigation Local Reflectivity**.



THREE-DIMENSIONAL THINKING

For Earth to radiate thermal energy, it must first absorb thermal energy. However, some natural surfaces on Earth and in the atmosphere are more reflective than absorbent. Examine the photo below.



Use the photo to describe areas of high and low albedo. Explain your reasoning.

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COLLECT EVIDENCE

How did the color of each container in the opening activity impact how it absorbed and reflected solar radiation? Record your evidence (E) in the chart at the beginning of the lesson.

A Closer Look: Monitoring Earth's Albedo



Images obtained from satellites greatly improve our understanding of Earth. An instrument aboard NASA's *Terra* and *Aqua* satellites, called the Moderate Resolution Imaging Spectroradiometer (MODIS), monitors Earth's albedo on a daily basis. The orbits of *Terra* and *Aqua* are timed so that one passes from north to south across the equator in the morning, while the other passes south to north over the equator in the afternoon. Together these satellites collect data on Earth's entire surface every one to two days.

Ice and snow have high albedos.

Engineers are able to use data collected by satellites to generate images of worldwide seasonal changes in ice coverage on land, as shown above. Why is this information important to scientists? Images like these help scientists improve global weather forecasting and climate prediction.

Melting snow or sea ice can affect climate. If incoming solar energy is absorbed at Earth's surface, the planet becomes warmer; if the energy is reflected into space, the planet becomes cooler. Snow or ice reflects more solar energy than land or water does. Most of the sunlight that hits snow or ice is reflected back into space. Reflection helps keep surface temperatures and air temperatures low. Monitoring Earth's albedo allows scientists to assess changes in Earth's global temperature.



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It's Your Turn

Reason In the past, a continental ice sheet covered much of North America. Hypothesize how the melting of the ice sheet affected the temperature of North America. Compile a class list of each person's hypotheses. Discuss any similarities and differences among your ideas.

Review

Summarize It!

1. **Diagram** Create a visual to show how energy is transferred from the Sun to Earth and the atmosphere. Include how features on Earth's surface affect this transfer of energy.



Three-Dimensional Thinking

Natia set up an investigation to model heat absorption and release for soil and water. She began by filling one container with water and one container with soil. She measured the initial temperature of the water and the soil. She then exposed both the water and the soil to a heat lamp for 2 minutes. After the time was up, she turned off the light and measured the temperature of both the water and the soil. Her results are indicated in the table below.

Surface Type	Temperature Before	Temperature After
Soil	25°C	27°C
Water	24°C	32°C

2. Are Natia's results valid?

- A No. Soil absorbs heat faster than water and therefore the temperature of the soil after exposure to the light should be higher than the water.
- B No. The temperature of the soil and water should be the same after exposure to the light.
- C Yes. Water absorbs heat faster than soil and therefore her temperature readings are accurate after exposure to the light.
- D Yes. Molecules in water are more compact and therefore retain heat better than soil.

3. How is conduction related to cold air temperatures at the poles, which are covered with ice and snow?

- A Ice and snow cannot conduct as much thermal energy to the atmosphere because the particles that make up ice and snow are more compacted and therefore they absorb and retain little thermal energy.
- B Ice and snow cannot conduct as much thermal energy to the atmosphere because they reflect more solar energy than they absorb.
- C The absorption rate of ice and snow allows for a greater amount of solar energy to be conducted to the atmosphere.
- D The reflectivity of snow and ice allows for a greater amount of solar energy to be conducted to the atmosphere because more solar energy is exposed to the air particles.

Real-World Connection

4. **Explain** How can the Sun continue to heat the atmosphere at night?

5. **Predict** Are temperatures typically cooler in rural areas or in urban cities?

Explain your reasoning.



Still have questions?

Go online to check your understanding about how solar energy warms Earth and the atmosphere.

REVISIT SCIENCE PROBES

Do you still agree with the statement you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that statement now.

EXPLAIN THE PHENOMENON



Revisit your claim about how the Sun warms Earth. Review the evidence you collected. Explain how your evidence supports your claim.

START PLANNING

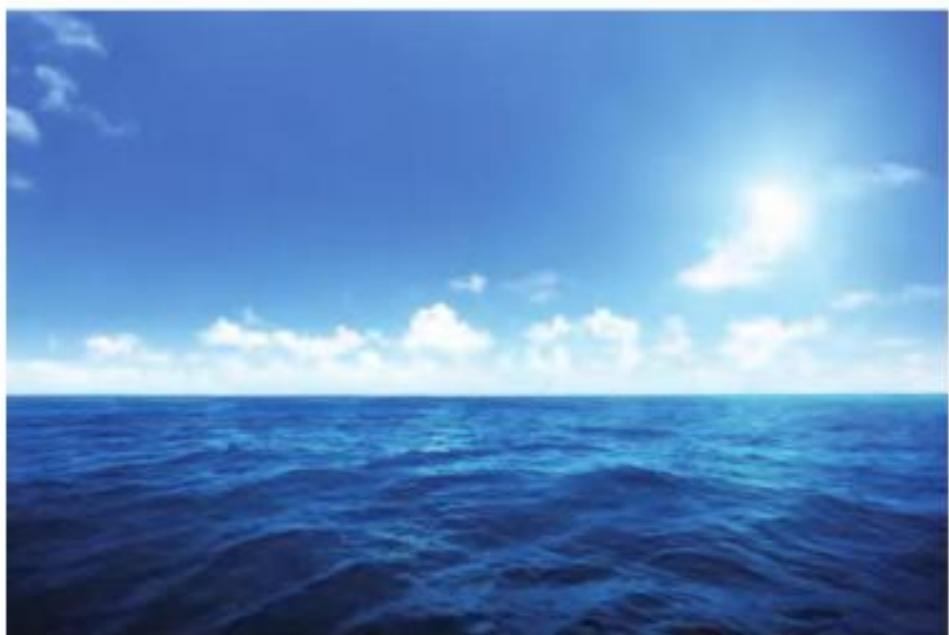
STEM Module Project Science Challenge

Now that you have learned about how energy from the Sun warms Earth and the atmosphere, go to your Module Project to begin planning your model. Keep in mind that you want to show how the Sun's energy is transferred throughout Earth's systems.



LESSON 2 LAUNCH

Moving Ocean Water



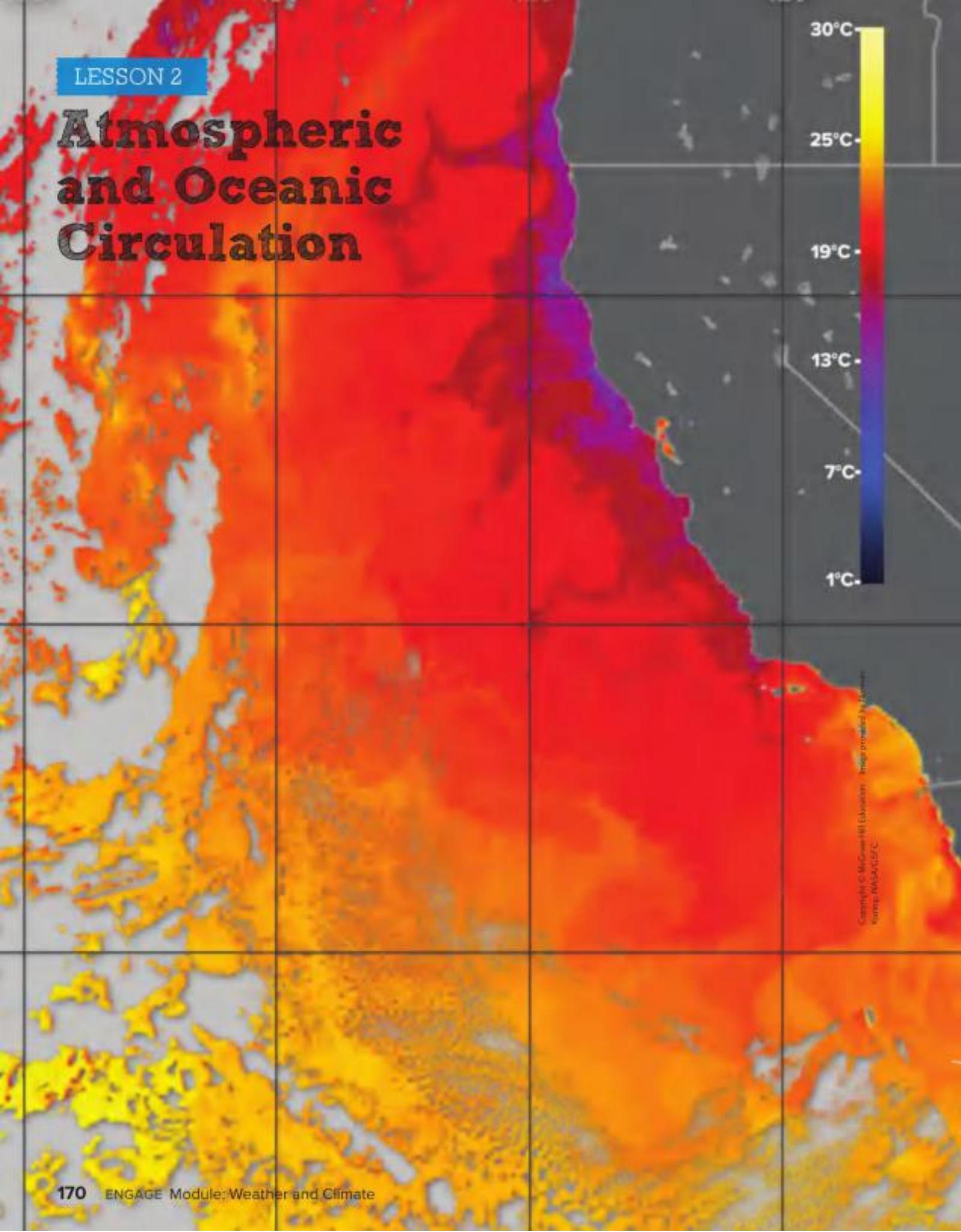
Ocean currents carry water in a certain direction. Check off all the different directions that describe how ocean currents can move water.

- Horizontally across the surface of the ocean
- Horizontally 100 meters beneath the surface
- Vertically up toward the surface of the ocean
- Vertically down to the deeper parts of the ocean

Explain your thinking. Describe your ideas about how ocean currents move.

You will revisit your response to the Science Probe at the end of the lesson.

Atmospheric and Oceanic Circulation



ENCOUNTER THE PHENOMENON

Why is water off the coast of northern California typically colder than water further offshore?

Examine the map of water temperatures off the coast of California. The purples and reds represent cooler waters, while the oranges and yellows indicate warmer waters. Why do you think water off the coast of California is typically colder than the adjacent waters?



GO ONLINE

Watch the animation *Between Wind and Water* to see this phenomenon in action.

Record your observations about the phenomenon in the space provided. Then, revise your thoughts above with what you observed in the animation.

EXPLAIN THE PHENOMENON

Did you see how the movement of air can affect the movement of water? Use your observations about the phenomenon to make a claim about why water off the coasts of some continents is typically colder than water further offshore.

CLAIM

Water off the coasts of some continents is typically colder than water further offshore because...

COLLECT EVIDENCE

as you work through the lesson.

Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain why wind blows?

B. What evidence have you discovered to explain why Earth has global wind systems?

MORE EVIDENCE

C. What evidence have you discovered to explain why ocean waters flow?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Water off the coasts of some continents is typically colder than water further offshore because...

D. What evidence have you discovered to explain how wind influences the movement of water?

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

Why does air flow?

Air is constantly moving. Early sailors relied on wind to move their ships around the world. Today, wind is used as a renewable source of energy, as shown in the figure. But why does air constantly move?

Earth does not have a giant fan creating wind across the globe. In the following activity, you will explore what causes air to flow on Earth's surface.



LAB Moving Air

Safety



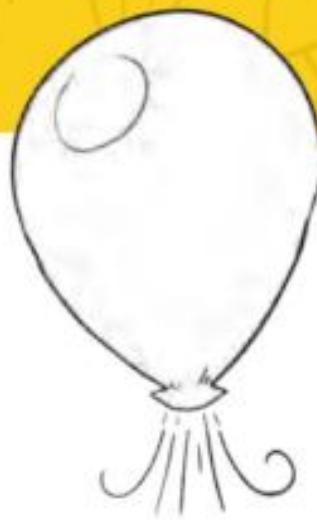
Materials

balloon

Procedure

1. Read and complete a lab safety form.
2. Inflate a balloon. Do not tie it. Hold the neck of the balloon closed.
3. Describe how the inflated balloon feels.

4. Open the neck of the balloon without letting go of the balloon. Record or illustrate your observations of what happens below.



Data and Observations

Analyze and Conclude

5. What do you think caused the inflated balloon surface to feel the way it did when the neck was closed?

6. Make a claim about what caused the air to leave the balloon when the neck was opened.



THREE-DIMENSIONAL THINKING

Imagine you are entering a large, air-conditioned building on a hot summer day. As you open the door, you feel cool air rushing past you out of the building. **Model** why you think this happens in the space below.



Want more information?

Go online to read more about the factors that influence atmospheric and oceanic circulation.

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

The Flow of Air You just discovered that differences in air pressure cause air to flow. **Wind** is the movement of air from areas of high pressure to areas of low pressure. The following activity explores two types of local winds—sea breezes and land breezes.

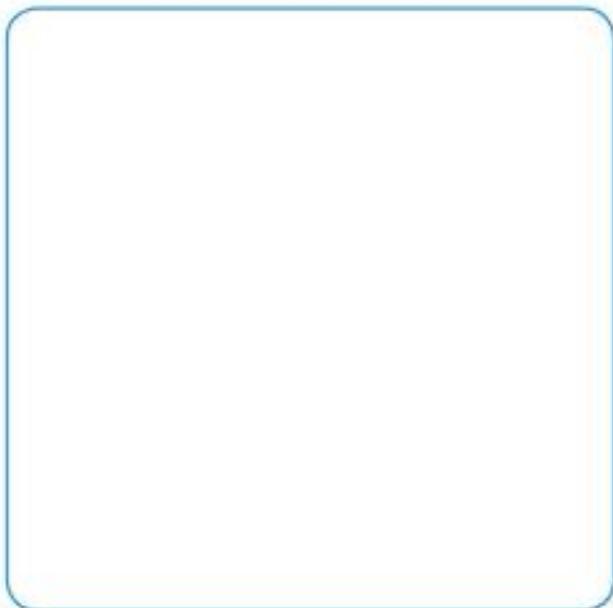
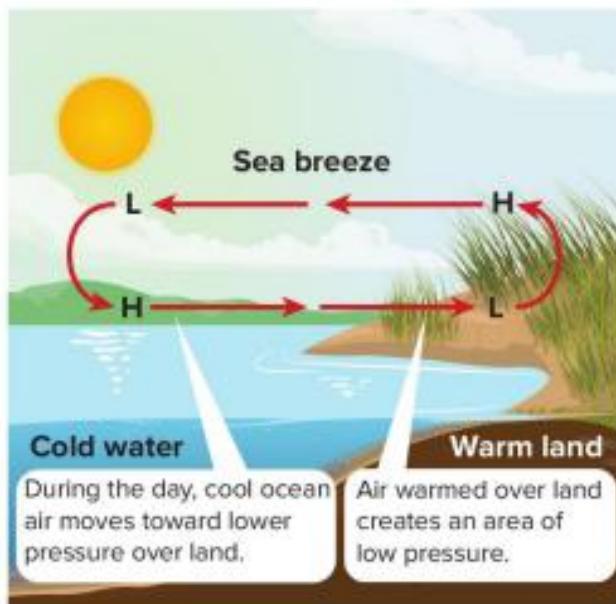
INVESTIGATION



It's a Breeze

 **GO ONLINE** to watch the animation *Sea Breezes and Land Breezes*.

1. Using what you learned in the animation, model the formation of a land breeze in the space below.



2. Predict whether a sea breeze could occur at night. Explain.

Temperature and Air Pressure Why are there differences in air pressure on Earth? Recall that the Sun's energy warms Earth unevenly. Warm air rises and puts less pressure on Earth than cooler air. Cold air sinks and puts more pressure on Earth. These differences in temperature create differences in air pressure, creating both local and global winds.

COLLECT EVIDENCE

What causes wind to blow? Record your evidence (A) in the chart at the beginning of the lesson.

What patterns do global winds form?

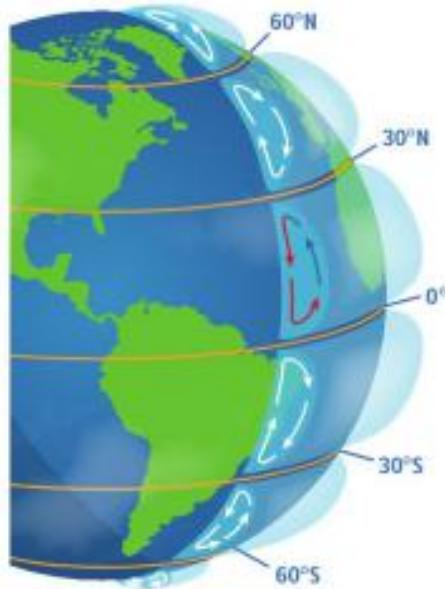
PHYSICAL SCIENCE Connection Recall that conduction occurs where the atmosphere contacts Earth. As molecules of air close to Earth's surface are heated by conduction, they spread apart, and air becomes less dense. Less dense air rises, transferring thermal energy to higher altitudes. The transfer of thermal energy by the movement of particles within matter is called **convection**.

Earth has several large convection cells that redistribute thermal energy around the world. Let's take a look at global convection in Earth's atmosphere.

INVESTIGATION

Rise and Fall, then Repeat

1. Study the diagram. Notice the direction of air flow in each convection cell. What general patterns can you identify?



2. Using your knowledge of conduction and convection, color the arrows of the cells red for warm or blue for cool. Some have already been colored in for you.

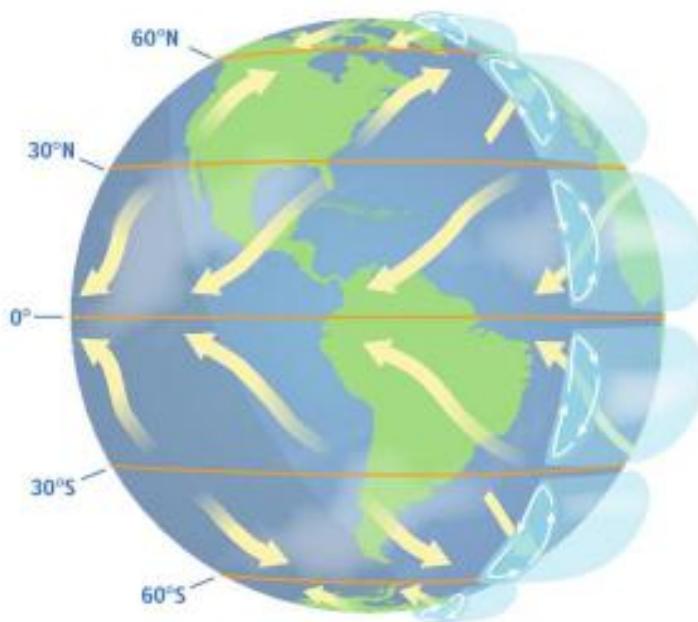
3. Why do you think air rises and sinks in global convection cells?

Global Winds Global convection cells help generate the three basic wind systems at Earth's surface in each hemisphere. In the following activity, you will explore the trade winds, westerlies, and polar easterlies.

INVESTIGATION

It's a Blowin'

1. Label the image with the global wind systems based on the descriptions below.



- The **polar easterlies** are cold winds that blow from east to west near the North Pole and the South Pole. Polar easterlies begin as dense polar air that sinks.
- The **prevailing westerlies** are steady winds that flow from west to east between latitudes 30°N and 60°N, and 30°S and 60°S.
- The **trade winds** are steady winds that flow from east to west between 30°N latitude and 30°S latitude.

2. In which direction do you think weather generally moves across the United States? Why?

Answer the question in the space below.



3. **HISTORY Connection** The trade winds were named by sailors, who took advantage of these winds to sail their ships across the oceans. It is the northeast trade winds that carried ships from Europe to the New World. Label the direction of the trade winds on the map below.



THREE-DIMENSIONAL THINKING

Why do you think there are many wind **systems** between a pole and the equator instead of just one large single wind system? Use your knowledge of the global convection cells to inform your reasoning.

COLLECT EVIDENCE

What are the global wind systems? Record your evidence (B) in the chart at the beginning of the lesson.

Why do the major wind systems blow in certain directions?

You probably noticed in the previous activity that the wind systems do not blow in straight lines. Instead, they curve in predictable patterns. Watch the demonstration to see why these patterns occur.

INVESTIGATION

Ahead of the Curve

1. Observe the demonstration. Record your observations below.

2. What did the line look like when the paper was not spinning?

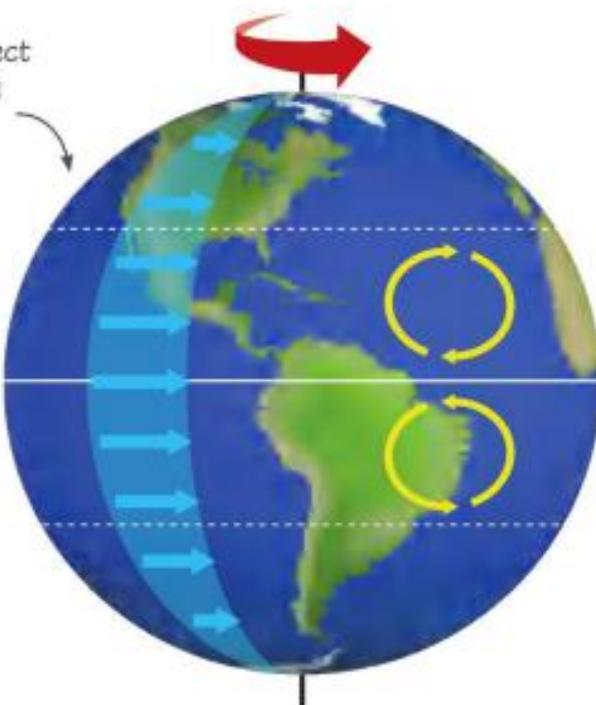
3. What did the line look like when the paper was spinning?

4. Why do you think the major wind systems blow in curved paths? Use evidence from the investigation to support your explanation.

Rotation of Earth What do you think happens when you throw a ball to someone across from you on a moving merry-go-round? The ball appears to curve because the person catching the ball had moved. In a similar way, Earth's rotation causes moving air and water to appear to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, a phenomenon known as the **Coriolis effect**. As you just investigated, the Coriolis effect describes how objects and fluid matter, like air and water, move in an apparent curved path rather than a straight line. It is the Coriolis effect that produces the curving patterns of circulating wind.

How does the Coriolis effect deflect air (and water) on Earth's surface?

1. Air is being carried around Earth by rotation. The surface has a greater velocity near the equator than at the poles because it has to travel a greater distance in 24 hours.



2. Therefore, as air moves toward the poles, it is rotating faster toward the east than the land over which it moves. It appears from the surface to be deflected to the east.

3. The opposite occurs as air moves toward the equator and encounters areas with a faster surface velocity. The air appears to lag behind, deflecting to the west as if it were being left behind by Earth's rotation.

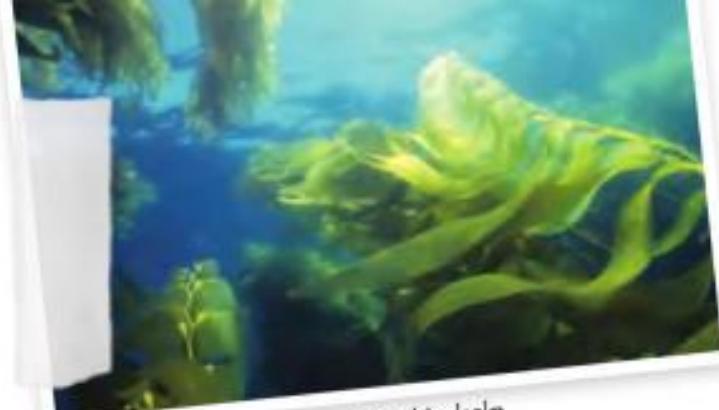
Effect of Landmasses The Coriolis effect is not the only factor that influences the motion of wind. Landmasses also affect the speed and direction of wind systems. For example, the westerlies in the Southern Hemisphere are locally very strong because this system is mostly over the oceans and has few continents to disrupt the wind.

Additionally, when wind meets a large feature, such as a mountain, it is deflected, or forced, upward, as shown in the photo to the right.



Why do ocean waters flow?

Now that you understand the factors that both create and affect the movement of air, let's take a look at the movement of water. The uneven heating of Earth has an effect on ocean water that is similar to its effect on air. It causes differences in physical properties that cause ocean water to flow. Let's investigate!



What causes this kelp to move underwater?

LAB Moving Water

Safety



Materials

dropper

glass beakers (4)

- 1 with 100 mL of cold, red salt water
- 1 with 100 mL of warm, yellow salt water
- 1 with 100 mL of cold, blue freshwater
- 1 with 100 mL of warm, clear freshwater



Procedure

1. Read and complete a lab safety form.
2. Using the dropper, put several drops of the cold, red salt water into the beaker with the warm, yellow salt water and observe what happens. Record your observations under Step 2 in the Data and Observations section on the following page.
3. Put several drops of the cold, blue freshwater into the beaker with the warm, clear freshwater and observe what happens. Record your observations under Step 3 on the following page.
4. Put several drops of the cold, blue freshwater into the beaker with the warm, yellow salt water and observe what happens. Record your observations under Step 4 on the following page.
5. Follow your teacher's instructions for proper cleanup.

Data and Observations

Step 2

Step 3

Step 4

6. Describe the movement of the cold, red salt water in Step 2. How does this compare to the movement of the cold, blue freshwater in Step 4?

7. Construct an explanation of the cause of the differences you observed in the model.

8. If you poured the four water samples into a graduated cylinder, how would they arrange themselves into layers by color, from top to bottom?



COLLECT EVIDENCE

Why do ocean waters flow? Record your evidence (C) in the chart at the beginning of the lesson.

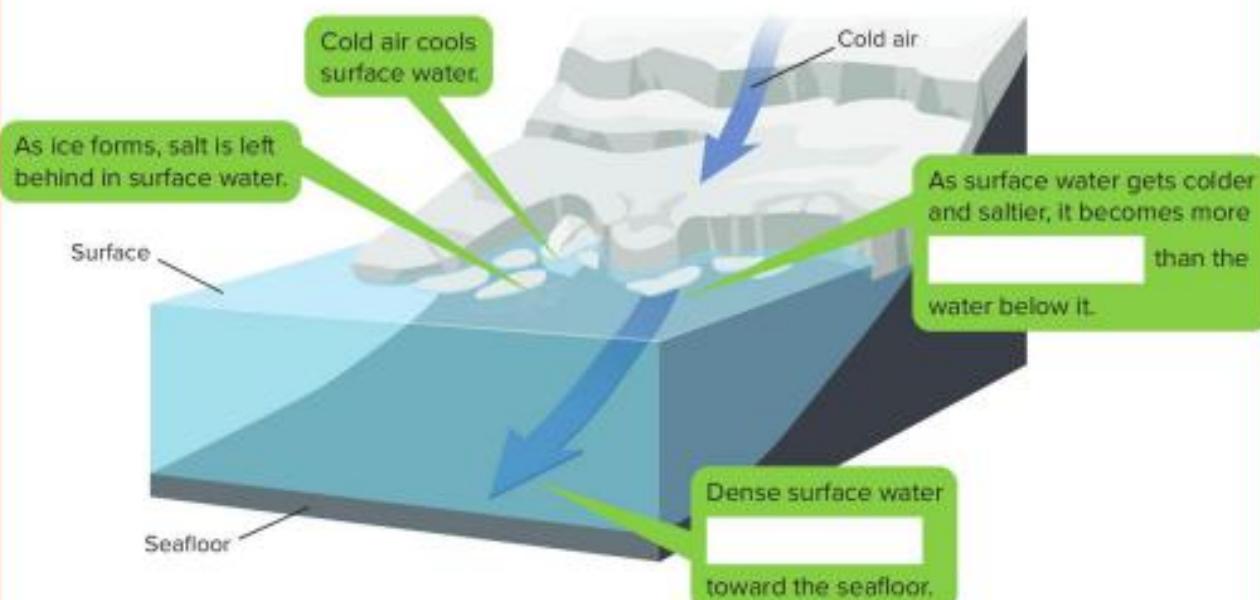
Density Currents In the previous activity you discovered that high salinity and cold temperatures cause water to become more dense. Like air, water that is more dense sinks. This helps create currents of water deep in the ocean as water flows from areas of high density to areas of low density. A **density current** is the vertical movement of water caused by differences in density.



THREE-DIMENSIONAL THINKING

Examine the diagram **modeling** the formation of a density current below.

1. Complete the sentences on the image.



2. With a partner, identify the components of this **system**.

3. Based on what you know about density currents, where do you think they form?

Surface Currents Ocean currents flow at different depths in the ocean. You've learned that density currents move water downward. They carry water from the surface to deeper parts of the ocean. So what causes surface waters to flow?



INVESTIGATION

It's on the Surface

1. Watch the demonstration performed by your teacher. Record your observations below.

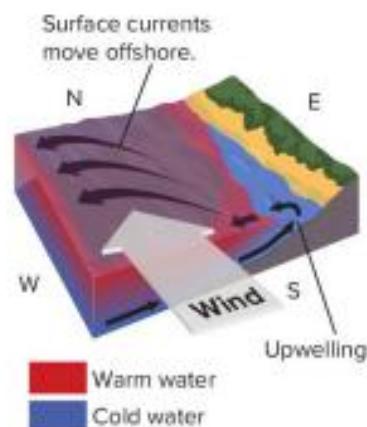
2. Explain the movement of the food coloring in the demonstration.

3. Make a claim about the cause of surface currents. Use evidence from the experiment to support your claim.



PHYSICAL SCIENCE Connection As you just discovered, a **surface current** is a wind-driven current that carries ocean water horizontally across the ocean's surface. As wind blows over ocean water, it transfers energy to the water. The moving air particles drag on the surface of the water and cause the top portion of the ocean to move.

Upwelling As surface currents move toward the poles, they cool and sink. Cold, dense water is brought back up to the surface through upwelling. **Upwelling** is the vertical movement of water toward the ocean's surface. Upwelling occurs when wind blows across the ocean's surface and pushes water away from an area. Deeper, colder water is then forced to the surface. This deeper, colder water is nutrient-rich and supports large populations of algae, fish, and other ocean organisms.



THREE-DIMENSIONAL THINKING

Using what you have learned about Earth's major wind systems, locate one coastline that might experience upwelling. Draw a diagram of the coastline in the space below. Label the continent and the wind **system**. Use arrows to **model** the directions of the wind system and the ocean waters.

COLLECT EVIDENCE

How does the wind influence the movement of water? Record your evidence (D) in the chart at the beginning of the lesson.

 **GO ONLINE** for an additional opportunity to explore!

Want to learn more about upwelling? Then perform the following activity.

Predict Use oceanographic data from satellites and moorings to plan a tour to best view blue whales in the **Lab Predicting Whale Sightings Based on Upwelling**.

Why do ocean currents flow in certain directions?

Recall that air flows in predictable directions. Do ocean currents also form patterns?

Cargo spills can help oceanographers study the direction of ocean currents. The longitude and latitude positions of items from spills that wash ashore contain clues about the direction and speed of currents. Interpret the data in the lab below to find out what happened to a cargo of rubber bath toys lost in a January 1992 storm in the North Pacific.

LAB Toys Ahoy

Materials

world map
map of global currents

Procedure

1. Mark the longitude and latitude positions from the table on the world map you receive from your teacher. The first data point represents the location of the cargo spill. The other data represent locations where individual bath toys were found. Label each point with a date.
2. Connect the dots in order of time. Ocean currents don't follow straight lines, so use curved lines. The toys could not float over land, so all the lines you draw should only cross water.



Found Toys		
Date	Latitude	Longitude
January 1992	45°N	178°E
March 1992	44°N	165°W
July 1992	49°N	155°W
October 1992	52°N	135°W
January 1993	59°N	149°W
March 1993	56°N	157°W
July 1993	57°N	170°W
October 1993	59°N	180°E
January 1994	56°N	166°E
March 1994	45°N	155°E
July 1994	47°N	172°E
October 1994	50°N	165°W
January 1995	47°N	140°W
October 2000	46°N	50°W
December 2003	57°N	07°W

Procedure, continued

3. How did the toys travel to the Atlantic Ocean? Using a map of global currents, sequence the currents that the toys rode in the space below.

Analyze and Conclude

4. What factors influence the direction of ocean currents? What evidence from the lab supports your explanation?

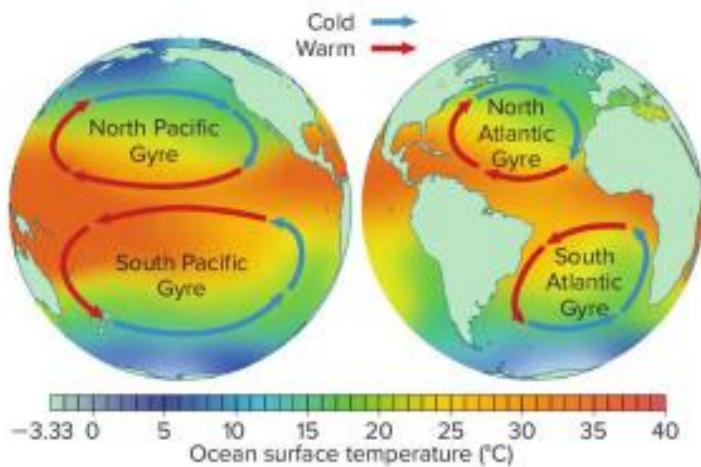


Influencing Factors As you just modeled in the *Toys Ahoy* lab, landmasses deflect the flow of ocean currents. They help create large circular systems of ocean currents called gyres. As shown on the map below, the currents within each gyre move in the same direction. However if you look closely, you can see that the direction of current movement in a gyre is different in each hemisphere.



THREE-DIMENSIONAL THINKING

Analyze the map of gyres below. Then answer the questions that follow.



1. In what direction do gyres flow in the Northern Hemisphere? What about in the Southern Hemisphere? Why do you think this **pattern** occurs?

2. Why are the major warm-water currents on the western boundaries of oceans and the major cold-water currents on the eastern boundaries of oceans? What explains this **pattern**?

3. What **energy** ultimately drives convection in the oceans?

What global pattern do ocean currents form?

Aside from gyres, there is another large system of ocean currents that circulate thermal energy around Earth. Let's take a look.

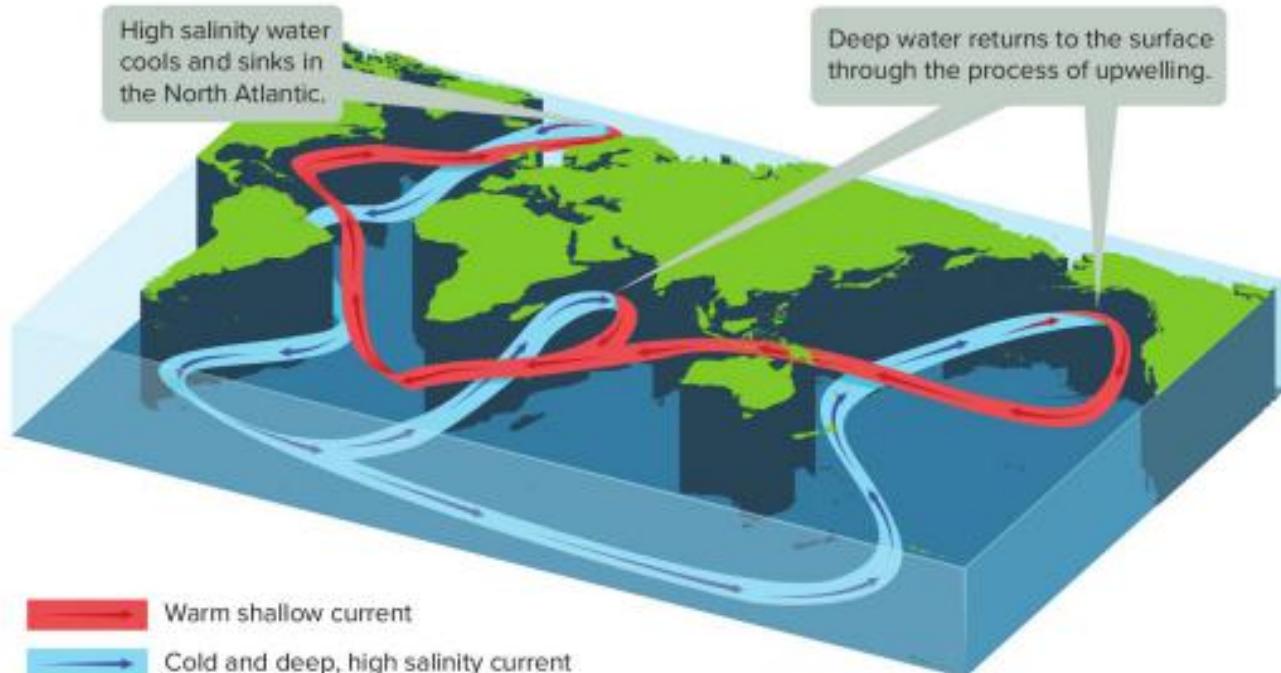
INVESTIGATION

The Great Ocean Conveyor Belt

 **GO ONLINE** to watch the animation *Great Ocean Conveyor Belt*.

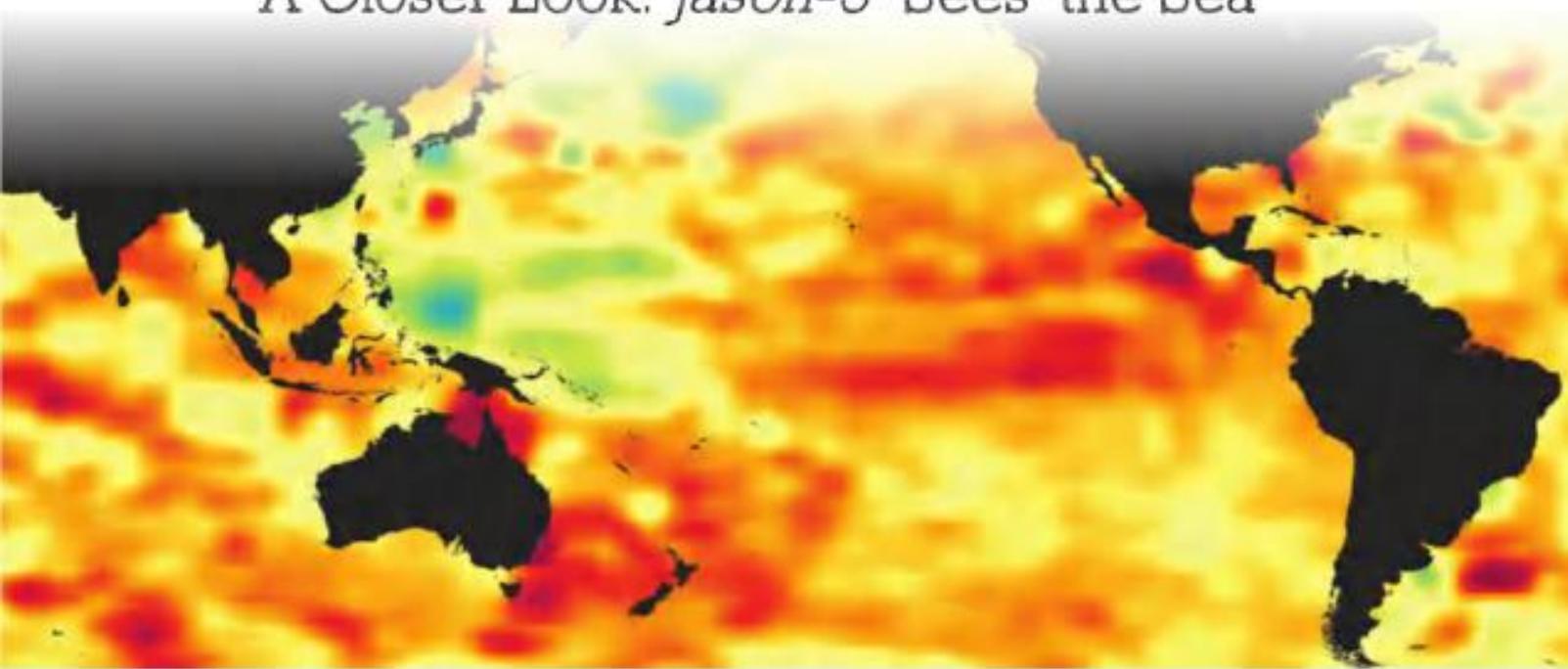
What is the Great Ocean Conveyor Belt and what does it affect?

Global Conveyor Belt Surface currents, upwelling, and density currents combine to form the Great Ocean Conveyor Belt, shown below. Variations in temperature and salinity drive this global pattern of interconnected ocean currents.



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A Closer Look: *Jason-3* “Sees” the Sea



Jason-3 is a satellite mission that uses radar to measure and map sea surface height, or ocean surface topography. Radar uses high-frequency signals that are transmitted from the satellite to the surface of the ocean. A receiving device then picks up the returning signal as it is reflected off the water.

The distance to the water's surface is calculated using the known speed of light and the time it takes for the signal to be reflected. These data are important for measuring variations in sea level and monitoring changes in global ocean currents and heat transfer. These changes are reflected in satellite-to-sea measurements and result in maps such as the one shown here. The map above was created using ocean surface topography measurements from the first ten days of data collected by *Jason-3*. The reds indicate higher-than-normal sea levels. Blue represents lower-than-normal sea levels.

Using *Jason-3* data, scientists are able to estimate global sea levels with an accuracy of just a few millimeters. Observations of ocean surface topography are used to enable more accurate ocean circulation, weather, and climate forecasts.



Copyright © McGraw-Hill Education. (b)NASA/JPL-Caltech/Ocean Surface Topography Science Team, (b)Stocktrek Images/Cartwright Images

It's Your Turn

Research What other technologies are used to study oceanic circulation patterns? Research and share your findings with the class.

Review

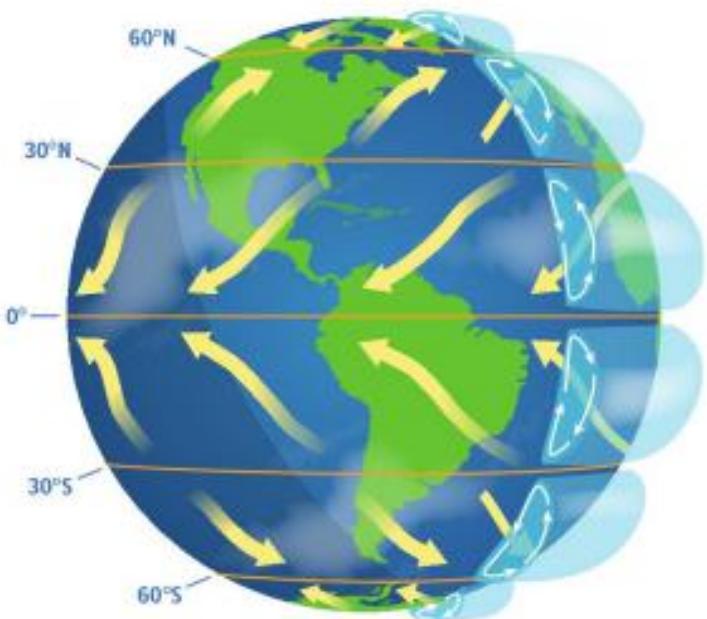
Summarize It!

1. **Diagram** Create a concept sketch that summarizes the role of density in the circulation of Earth's air and ocean water. Begin by listing the relationships you want to illustrate. Then, draw your sketch and write complete sentences describing the sketch.



Three-Dimensional Thinking

2. The diagram models convection cells and wind patterns over the globe. Which best summarizes what you can infer about their causes?



	Cause of Convection Cell	Cause of Wind Patterns
A	At the poles, ice caps reflect heat back into space. The air stays cold and sinks down under warmer air. At the equator, land and water absorb heat, which makes the air rise.	Earth's rotation produces the Coriolis effect, which makes the air move. At the same time, air in the upper atmosphere moves from low-pressure to high-pressure areas.
B	The Sun heats Earth's surface most at the poles. Here, warm air sinks down under cold air. At 60°N latitude and 60°S latitude, the air warms and rises into the upper atmosphere.	Air moves along Earth's surface in all directions from high-pressure areas. Earth's rotation produces the Coriolis effect, which bends the path of the moving air toward the south.
C	The Sun heats Earth's surface most at mid-latitudes. Here, warm air rises and cooler air moves in to replace it. At 30°N latitude and 30°S latitude, air in the upper atmosphere cools and sinks.	Air moves along Earth's surface from low-pressure areas to high-pressure areas. Earth's motion around the Sun produces the Coriolis effect, which makes the path of the moving air curve.
D	The Sun heats Earth's surface unevenly. At the equator, warm air rises and cooler air moves in to replace it. At the poles, cold air sinks down under warmer air.	Air moves along Earth's surface from high-pressure areas to low-pressure areas. Earth's rotation produces the Coriolis effect, which makes the path of the moving air curve.

Real-World Connection

3. **Explain** why the wind direction is often the same in Hawaii as it is in Greenland.

4. **Hypothesize** why hurricanes might be more common in the eastern United States than in the western United States.



Still have questions?

Go online to check your understanding about air and water circulation.

REVISIT



Do you still agree with the answer you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that answer now.

EXPLAIN THE PHENOMENON



Revisit your claim about why water along some coastlines is cooler than water further offshore. Review the evidence you collected. Explain how your evidence supports your claim.

KEEP PLANNING

STEM Module Project Science Challenge

Now that you've learned about patterns of atmospheric and oceanic circulation, go back to your Module Project to continue planning your model. Keep in mind that you want to explain the factors that influence the movement of air and water, and how water transfers heat around the globe.



LESSON 3 LAUNCH

Air Pressure Ideas



Seven students looked at a barometer, a weather device that measures air pressure. They had different ideas about air pressure. This is what they thought:

Kimberly: I think air has to be moving to create air pressure.

Glenn: Air pressure is a downward force.

Rae: The higher in the atmosphere, the greater the air pressure.

Jeff: Air pressure is the same in all directions.

Oliver: Air pressure increases as the number of air particles increases.

Cameron: Warm air masses have higher pressure than cool air masses.

Jay: When air pressure decreases, it might rain or snow.

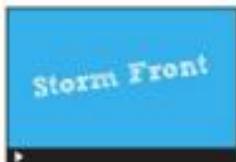
Circle the names of the students you agree with and describe why you agree. Describe your ideas about air pressure.

You will revisit your response to the Science Probe at the end of the lesson.

Weather Patterns

ENCOUNTER THE PHENOMENON

What causes weather to change?



GO ONLINE

Watch the video *Storm Front* to see this phenomenon in action.

In the space below, describe the progression of how the weather changed from the beginning to the end of the video.

Why do you think weather changes?

A simple line drawing of a cloud with rain falling from it.

EXPLAIN THE PHENOMENON

You just watched a video showing the passing of a storm over an area. Are you starting to get some ideas about how weather changes? Use your observations from the video to make a claim about what factors cause weather to change.

CLAIM

Weather changes because...

COLLECT EVIDENCE

as you work through the lesson.

Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to describe the relationship between weather and weather variables?

B. What evidence have you discovered to explain how air masses contribute to weather?

C. What evidence have you discovered to explain the relationship between pressure systems and weather?

MORE EVIDENCE

D. What evidence have you discovered to explain what happens when air masses collide?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Weather changes because...

E. What evidence have you discovered to explain how weather is predicted?

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

How is weather described?

Before you leave for school in the morning, you might check a weather report to see whether you'll need sunglasses or an umbrella that day. Weather reports use numbers and certain vocabulary terms to help you understand the weather conditions. Let's investigate the information given in a typical weather report.



INVESTIGATION

Listen Up

1. In the space below, make a list of data you would expect to hear in a weather report.

2. Listen carefully to the weather report provided by your teacher. Jot down numbers and measurements you hear. Listen a second time and make adjustments to your original notes, such as adding more data, if necessary.

3. Was all of the data you expected to hear in the weather report present? If not, what data was excluded from the weather report?

4. Which terms or measurement units were unfamiliar to you, or difficult to understand?

5. Why do you think so many different types of data are needed to give a complete weather report?



6. Can you explain what weather is in your own words?





Want more information?

Go online to read more about the relationship between air masses and changes in weather conditions.

FOLDABLES®

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Weather Factors The atmospheric conditions, along with short-term changes, of a certain place at a certain time is **weather**. Meteorologists, scientists who study and predict weather, use several specific factors, or variables, to describe a variety of atmospheric conditions. These variables include temperature, air pressure, humidity, precipitation, and wind.

INVESTIGATION



Describing Weather

WRITING Connection Research how each variable contributes to weather in the space provided. Describe each weather variable in detail and how the variable is measured. Quote or paraphrase the data you collect.

Weather Variables	
Temperature	
Air Pressure	

Wind Speed	
Humidity	
Precipitation	



COLLECT EVIDENCE

What is the relationship between weather variables and weather?
Record your evidence (A) in the chart at the beginning of the lesson.

How does Earth's surface affect the air above it?

Weather changes minute to minute and day to day. But sometimes the weather stays the same for several days in a row. For example, during winter in the northern United States, extremely cold temperatures and dry conditions often last for three or four days in a row. This can be followed with warmer temperatures and snow showers. What influences the characteristics of air?

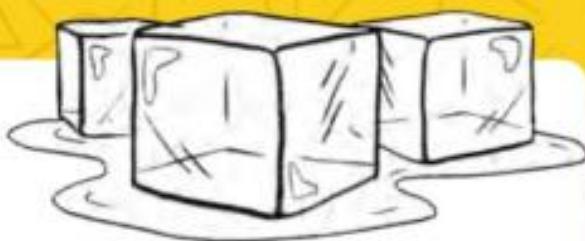
LAB Feel the Air

Safety



Materials

small containers (3)	hot water	plastic wrap
ice	large containers (3)	



Procedure

1. Read and complete a lab safety form.
2. Place ice in the first small container and hot water in the second small container. Leave the third small container empty.
3. Place each small container in its own large container. Cover each large container with plastic wrap.
4. After 5 minutes, peel back a corner of the plastic wrap for each large container and place your hand inside the large container to feel the air. Record your observations in the Data and Observations section below.
5. Follow your teacher's instructions for proper cleanup.

Data and Observations

Analyze and Conclude

6. What evidence can you provide that the air in the large containers was influenced by the material in the small container?

Air Masses You just explored how air above an area can be influenced by the surface below. Now you will learn about why this phenomenon occurs. Let's investigate air masses and the characteristics that describe them.

INVESTIGATION

Characteristics of Air Masses

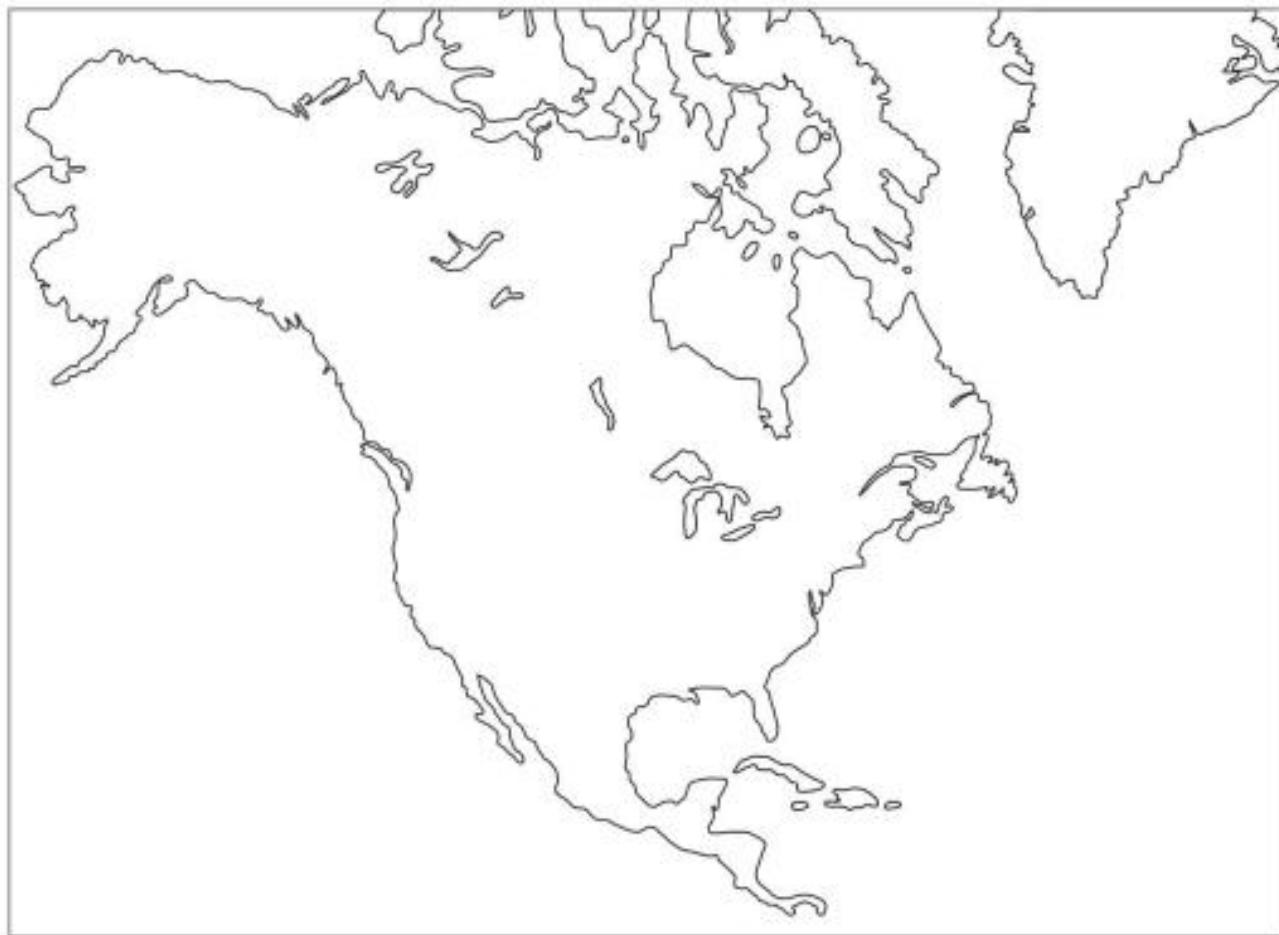


 **GO ONLINE** Watch the animation *Air Masses*. Use information in the animation to answer the questions below.

1. What are air masses and how do they form?

2. What characteristics do air masses take on from the surface they form over?

3. On the map below, illustrate the locations of air masses that impact North America. Include the temperature and moisture characteristics that are common to each air mass.



4. What patterns do you observe among the temperature and moisture content of air masses that form over North America?

5. What happens when an air mass moves?

Read a Scientific Text

As you have discovered, **air masses** are large bodies of air that have uniform temperature, humidity, and pressure. Regardless of where they form, air masses can change as they move over Earth's surface, resulting in changes in weather. What causes air masses to move?

CLOSE READING

Inspect

Read the passage *Jet Streams and Weather*.

Find Evidence

Reread the third paragraph. Underline evidence to support the influence of the jet stream on air masses.

Make Connections

Research the jet stream and its effects on weather in the United States. Compare and contrast the information gained from this text with the information you gain from your research. Assess the credibility and accuracy of each source you use.

Jet Streams and Weather

Near the top of the troposphere are narrow bands of high winds called jet streams. Jet streams flow around Earth from west to east, often making large loops to the north or the south. Two jet streams directly affect the Northern and Southern hemispheres: polar jet streams and subtropical jet streams. Polar jets are located around 30°N and 30°S of the equator. Subtropical jets are located around 60°N and 60°S of the equator.

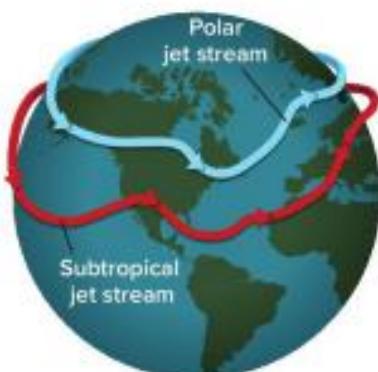
So what causes these areas of high winds? Recall that air moves from areas of high pressure to low pressure. Wind strength increases when temperature changes between two locations increase. Polar jets and subtropical jets are located in areas on Earth where temperature changes in the upper atmosphere are the greatest. For example, the polar jet stream forms at the boundary of cold, dry polar air to the north and warmer, moist air to the south. Jet streams can move at speeds up to 300 km/h and are more unpredictable than prevailing winds.

When the upper level winds of the jet stream encounter an air mass, they direct cooler air masses toward the equator and warmer air masses toward the poles. As air masses move, they bring with them the temperatures, pressure, and moisture content of their source area to new regions on Earth, resulting in a change of weather. Storms form along jet streams and generate large-scale weather systems. These systems transport cold surface air toward the tropics and warm surface air toward the poles. Weather systems generally follow the path of jet streams. Jet streams also affect the intensity of weather systems by moving air of different temperatures from one region of Earth to another.

HISTORY Connection Jet streams were discovered during World War II, when American pilots flew their bombers higher than normal to avoid anti-aircraft fire. At those high altitudes, their speeds increased in some areas. The only logical explanation was that the planes had entered a stream of swiftly moving air.

COLLECT EVIDENCE

How do air masses contribute to weather? Record your evidence (B) in the chart at the beginning of the lesson.



How do differences in pressure affect weather?

Recall that air pressure is the weight of the molecules in a large mass of air. When air molecules are cool, they are closer together than when they are warm. Cool air masses have high pressure, or more weight. Warm air masses have low pressure, or less weight.

INVESTIGATION

Pressure Changes

1. Observe the temperature and pressure of two locations. In each circle, model the distribution of air molecules based on the location's temperature and pressure.

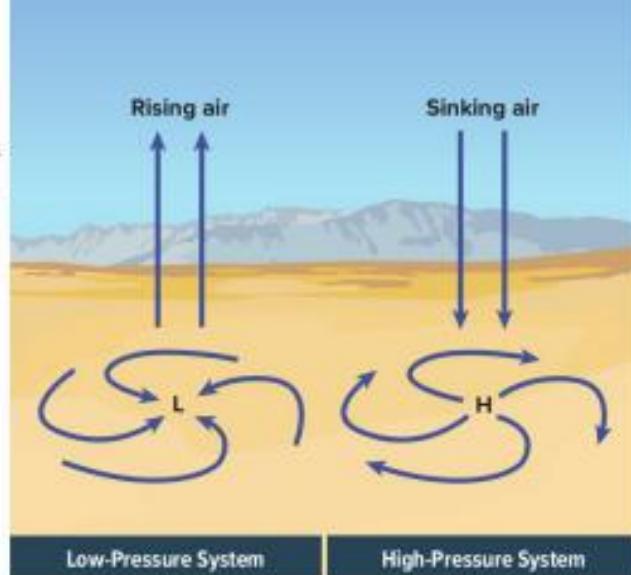


2. Based on the distribution of molecules, describe whether you think air in a high-pressure system rises or sinks. Explain your reasoning.

3. Think back to Lesson 1. Explain why the temperature on land is higher than the temperature over water.

Pressure Systems As you observed in the activity on the previous page, warm air puts less pressure on Earth than cooler air. As a result, air in a low-pressure system rises. Cool air puts greater pressure on Earth than warmer air. As a result, air in a high-pressure system sinks.

Also, notice that in the Northern Hemisphere, Earth's rotation causes winds to blow counterclockwise around a low-pressure system and converge. Around a high-pressure system, the winds blow clockwise and diverge.



Low-Pressure System

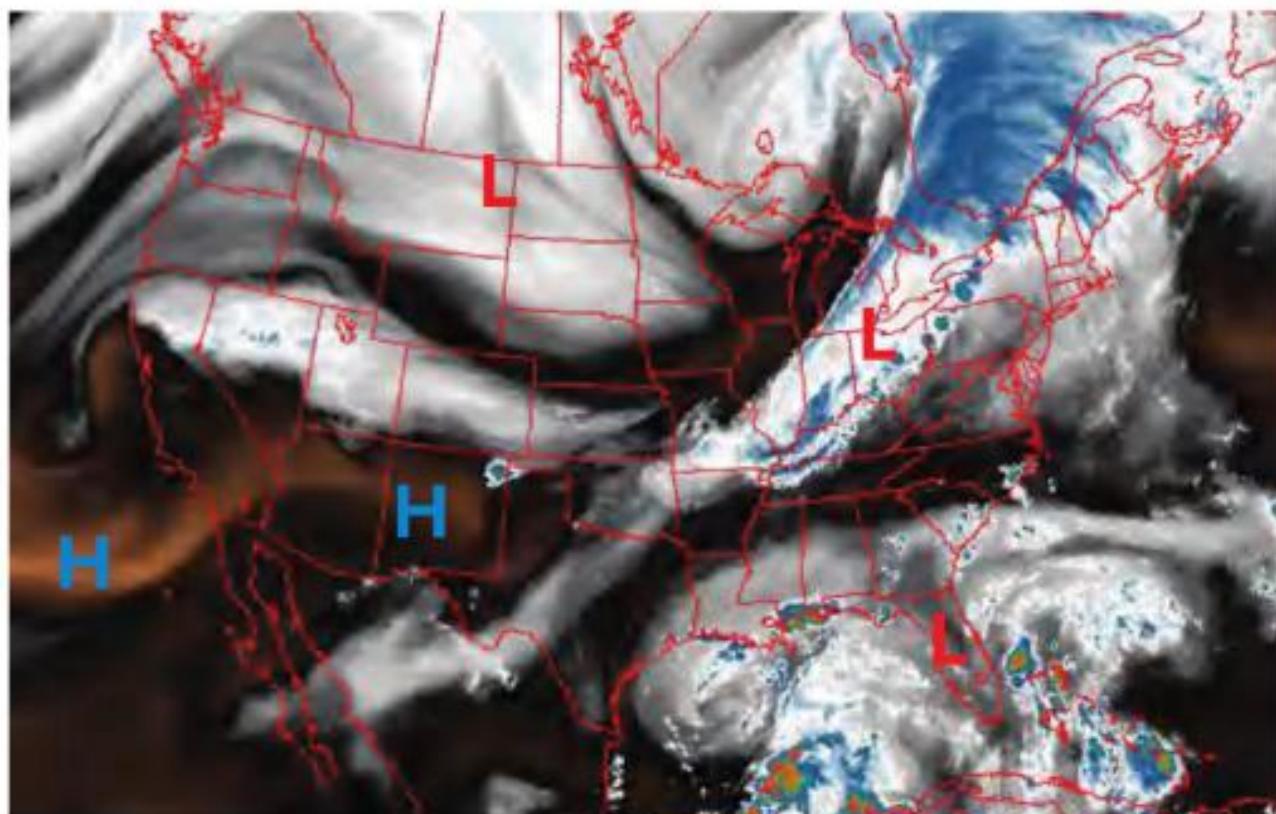
High-Pressure System

INVESTIGATION

Highs and Lows

The image below shows the amount of water vapor in the atmosphere. Bright and colored areas indicate areas of high moisture content. Black and brown areas indicate little or no moisture present.

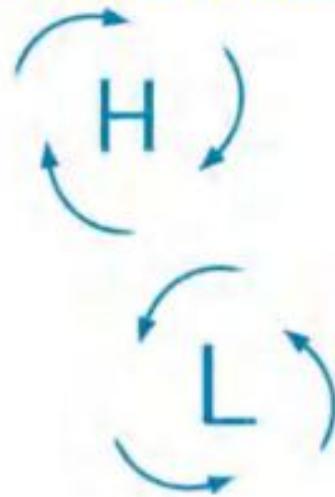
1. Locate the areas of high pressure (H) and low pressure (L) on the map.



2. What weather patterns do you observe with each type of pressure system?

3. Infer why the weather patterns you observed are associated with each type of pressure system.

Weather Conditions and Pressure Systems You just observed weather conditions associated with high- and low-pressure systems. Did you notice there was little to no cloud cover and precipitation in areas of high pressure? In a high-pressure system, cool, dense air sinks and clouds cannot form. High-pressure systems often bring clear skies and fair weather. Did you notice that clouds and precipitation were common in areas near low-pressure systems? In a low-pressure system, warm, less dense air rises. This rising air cools and water vapor in the air condenses. Therefore, a low-pressure system is often associated with cloudy weather and precipitation.



COLLECT EVIDENCE

What type of pressure system is responsible for the weather you observed at the beginning of the lesson? Record your evidence (C) in the chart at the beginning of the lesson.

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What happens when air masses meet?

As you learned previously, air masses bring with them the characteristics of their source region as they move. As wind carries an air mass away from the area where it formed, the air mass will eventually collide with another air mass. A **front** is a boundary between two air masses. Recall that air masses can be warm or cool depending on the source region in which they form. Let's investigate what happens when different types of air masses meet.

Air Mass Collision Course

1. Predict what happens when a cold air mass moves toward a warm air mass.

2. Predict what happens when a warm air mass moves toward a cold air mass.



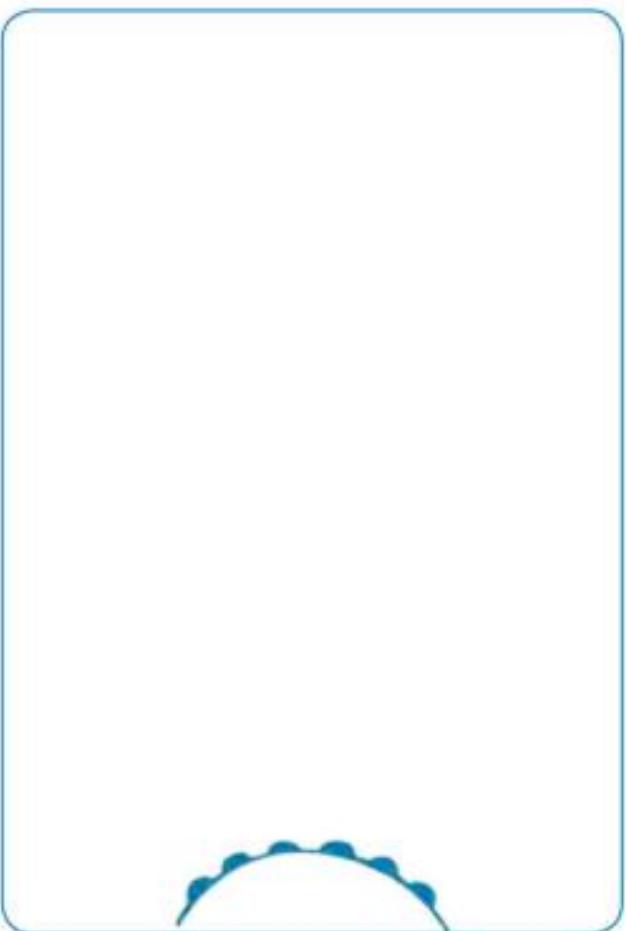
GO ONLINE Now, watch the animation *Fronts*. Then answer the questions that follow.

3. Create a diagram to show the interaction of air masses at a cold front and a warm front. Describe what happens as the air masses interact and what type of weather is caused by this interaction.

Cold Front



Warm Front



4. Explain how the information presented in the animation supported or refuted your original predictions.

5. Imagine it is winter. Explain how winds, air pressure, temperature, and relative humidity would change after a warm front has moved through the area.



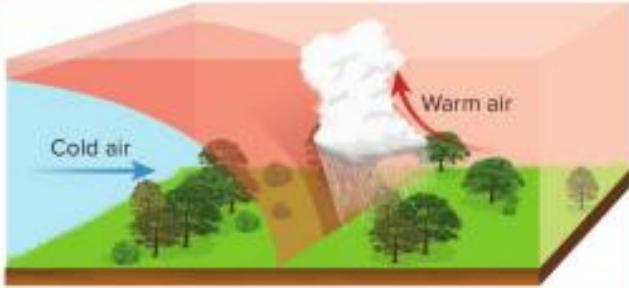
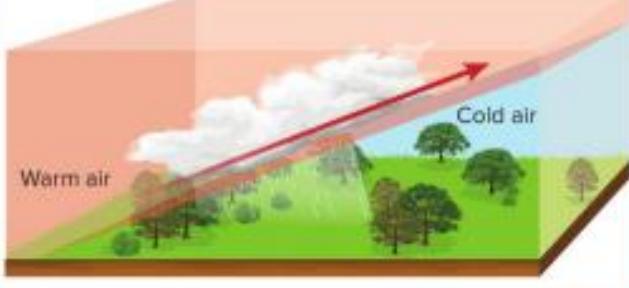
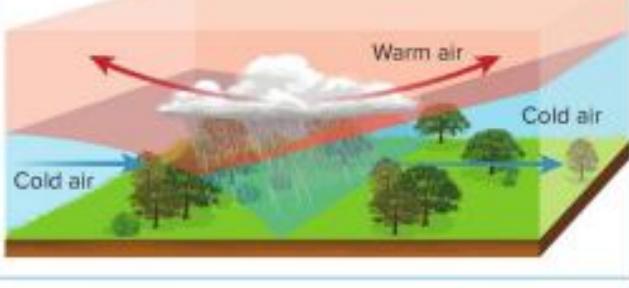
5. Imagine it is winter. Explain how winds, air pressure, temperature, and relative humidity would change after a warm front has moved through the area.



6. It is 9 AM on a summer day, and a cold front is supposed to move into your area by 12 PM. You are planning to leave for a trip to the beach in an hour. Will the weather spoil your plans? Explain.

7. What type of weather would be associated with the area where two air masses meet? Explain your reasoning.

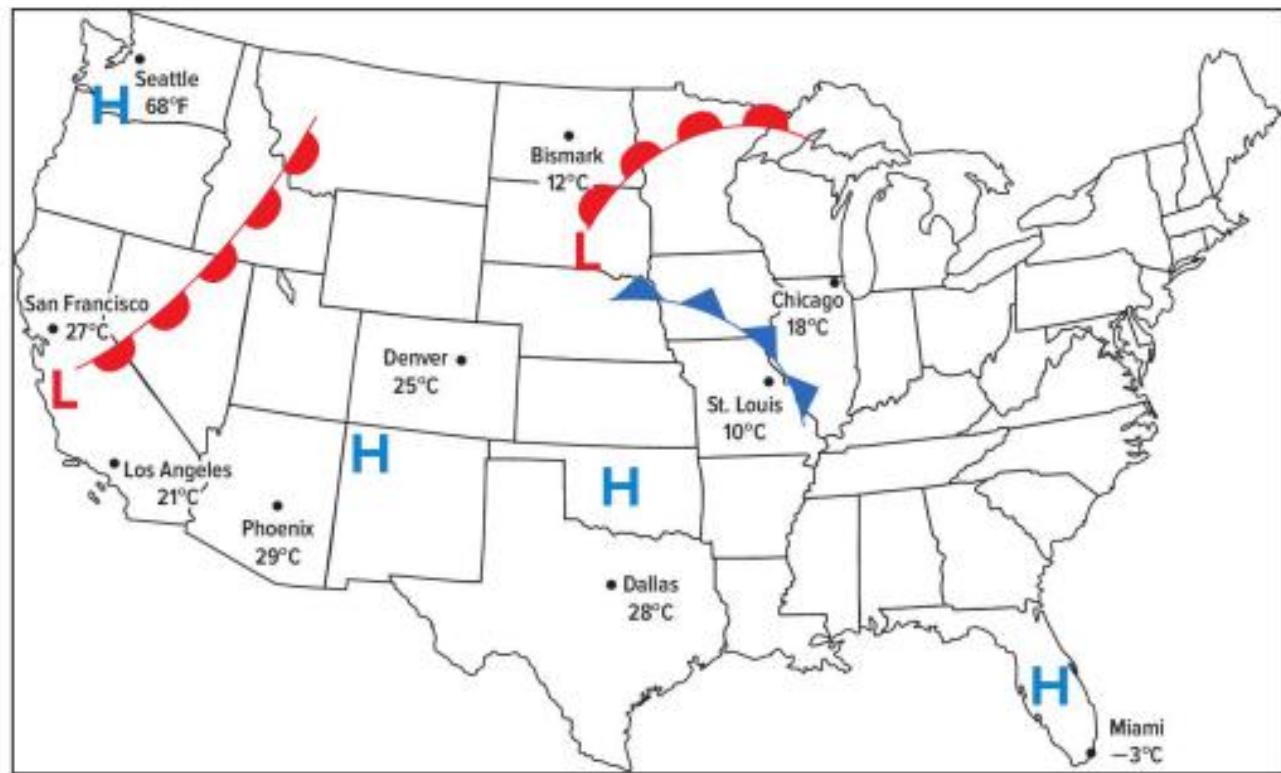
Fronts You just learned about what happens at warm and cold fronts and the resulting weather. Two other types of fronts, stationary and occluded, are also common. Let's examine each type of front in the table below.

Type of Front	Diagram
Cold A cold front forms when a colder air mass moves toward a warmer air mass. The cold, denser air pushes underneath the warm, less dense air mass. The warm air rises and cools. Water vapor in the air condenses and clouds form.	
Warm A warm front forms when less dense, warmer air moves toward colder, denser air. The warm air rises as it glides above the cold air mass. The water vapor in the air condenses, creating a wide blanket of clouds.	
Stationary Sometimes an approaching front will stall for several days with warm air on one side of it and cold air on the other side. When the boundary between two air masses stalls, a stationary front forms. Cloudy skies and light rain are found along stationary fronts.	
Occluded Cold fronts move faster than warm fronts. When a fast-moving cold front catches up with a slow-moving warm front, an occluded front forms. Occluded fronts usually bring precipitation.	

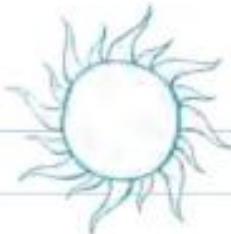
Weather Associations Weather is often associated with pressure systems. Because air moves from high pressure to low pressure, the air inside the high-pressure system moves away from the center. Warm, dense air sinks, bringing clear skies and fair weather. In a low-pressure system, the air rises causing water vapor to condense. Let's investigate further!

Come Rain or Shine

Examine the map and answer the questions below.



1. Which cities are experiencing clear, dry conditions? Explain why these conditions are occurring.



2. Which cities are probably experiencing stormy conditions or rainy weather? Explain why these conditions are occurring.

3. What type of front passed through St. Louis? Explain the type of weather they experienced as the front passed.

4. What type of front passed through San Francisco? Explain the type of weather they experienced before and after the passing of the front.

5. **MATH Connection** It is 68°F in Seattle and 27°C in San Francisco. In which city is the temperature higher?


A large rectangular box for writing the answer to question 5.

6. What does a negative number on the Celsius scale represent?

7. The weather station in Miami reported their temperature reading as -3°C. Argue whether you think this temperature was reported in error.

Changes in Weather at Frontal Boundaries Changes that occur at frontal boundaries include the following:

- Sharp temperature changes over a relatively short distance
- Change in moisture content (humidity)
- Rapid shifts in wind speed and direction
- Pressure changes
- Clouds and precipitation patterns



The tables below indicate how weather changes during a cold front and a warm front at a fixed location over time.

Cold Front			
Weather Variable	Before Passing	While Passing	After Passing
Temperature	Warm	Sudden drop	Cold
Air Pressure	Decreasing steadily	Leveling off	Increasing steadily
Winds	South-southeast	Shifting and gusty	West-northwest
Humidity	High	Sharp drop	Low
Precipitation	Showers	Heavy rains, storms may include hail, thunder, and lightning	Showers followed by clearing

Warm Front			
Weather Variable	Before Passing	While Passing	After Passing
Temperature	Cool, cold	Steady rise	Warmer
Air Pressure	Decreasing steadily	Leveling off	Slight increase, followed by a decrease
Winds	South-southeast	Shifting	South-southwest
Humidity	Steady rise	Steady	Rise, then steady
Precipitation	Light showers, snow, sleet, or drizzle	Light drizzle	none

COLLECT EVIDENCE

How do the collisions of air masses cause weather?

Record your evidence (D) in the chart at the beginning of the lesson.



How do meteorologists predict the weather?

Meteorologists need a true "snapshot" of the atmosphere at one particular moment to develop an accurate forecast. To obtain this, meteorologists analyze and interpret data gathered at the same time from weather instruments at many different locations. Meteorologists measure atmospheric conditions, such as temperature, air pressure, wind speed, and relative humidity. The quality of the data is critical for complete weather analysis and precise predictions. Two important factors in weather forecasting are the accuracy of the data and the amount of available data.

Let's investigate the accuracy of weather prediction.

LAB Predicting Weather

Materials

local weather maps

Internet access

Procedure

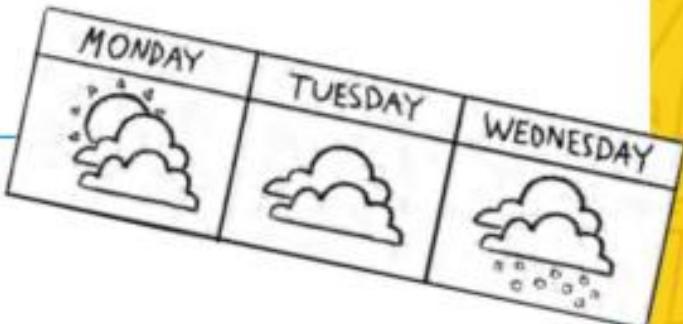
1. Read and complete a lab safety form.
2. **READING Connection** Locate a print or digital source from which you can collect weather data for a period of one week (7 days). Your data should include temperature, pressure, humidity, wind, and precipitation. What source did you choose to collect your data? How do you know that this is a credible and accurate source? Record your source evaluation in the space below.



Procedure, continued

3. Create a data table in the Data and Observations section below to record your data. Temperature, pressure, and humidity should be recorded as a number, but precipitation and wind conditions may be described in words.

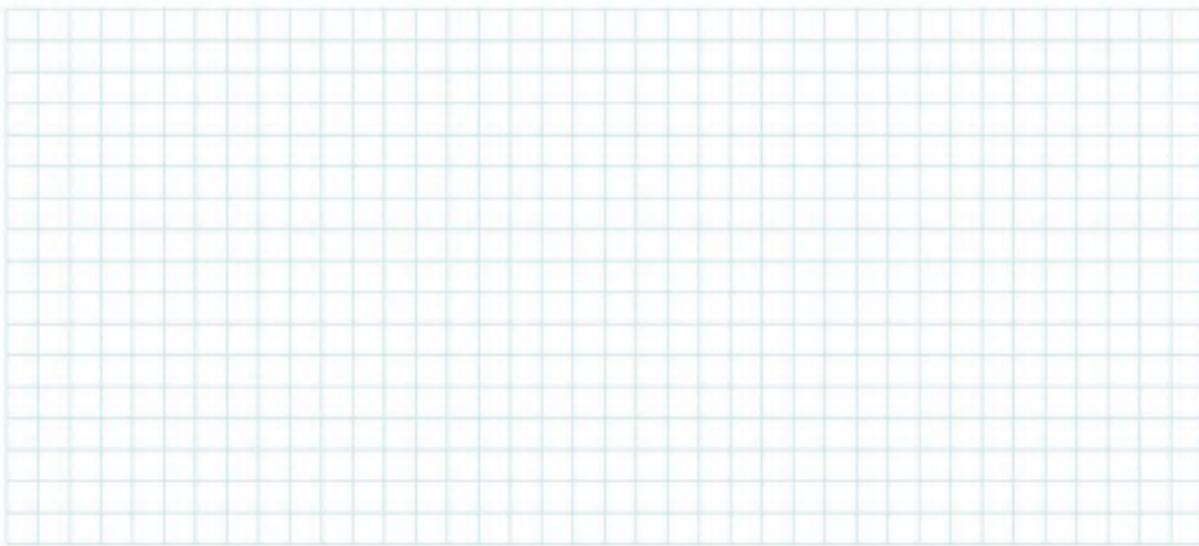
Data and Observations



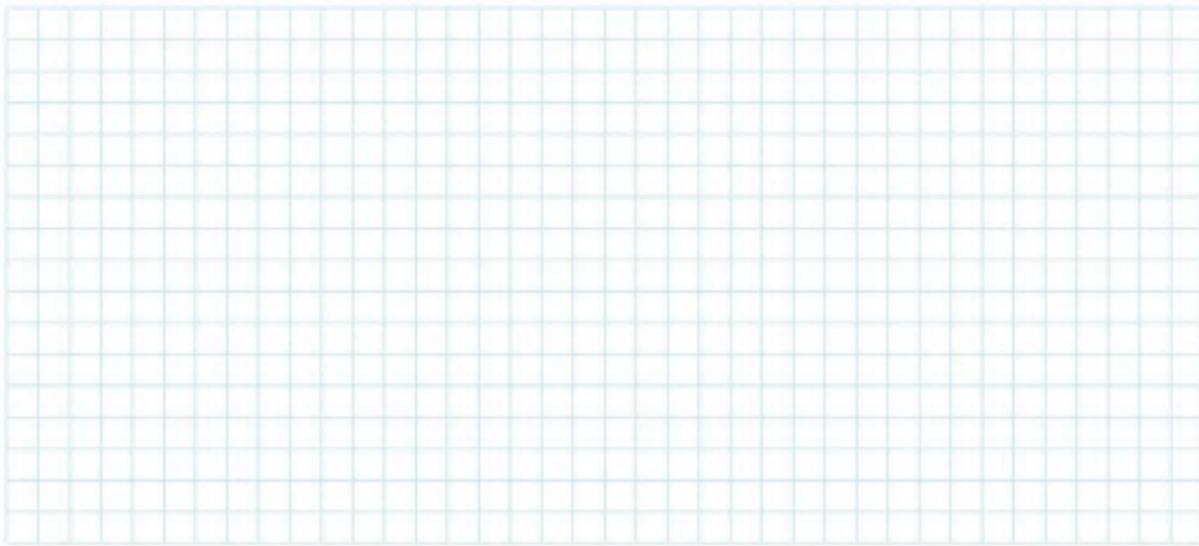
4. Describe how the evidence to be collected will be relevant to determining the relationship between patterns of air masses and changes in weather conditions.

5. Plot the temperature in degrees and air pressure in millibars on the graphs below. Beneath the graphs add notes to describe the humidity, wind conditions, and precipitation for each day.

Title:



Title:



Form Hypotheses

6. Examine your data and weather maps. Look for factors that appear to be related. For example, your data might suggest that when the pressure decreases, precipitation follows.
7. Find three sets of data pairs that seem to be related. Form three hypotheses, one for each set of data pairs. Write each of your hypotheses below.



Test Your Hypotheses

8. Look at your last day of data. Using your hypotheses, predict the weather for the next three days.

9. Collect weather data over the next three days and evaluate the accuracy of your predictions in the space below. Add to the table in step 3.



Analyze and Conclude

10. Compare your hypotheses with the results of your predictions. How successful were you? What additional information might have improved your predictions?

11. What evidence can you provide that the complex interactions of air masses result in changes in weather conditions?

12. Why do you think weather can only be predicted probabilistically?

OPEN INQUIRY

13. Investigate other forms of data you might collect and find out how they would help you to make a forecast. Plan an investigation using these newly determined variables to predict weather. Be sure to include in your plan the purpose of the investigation, how you will observe and record data—either firsthand or from a professional weather monitoring service—and the evidence to be collected. Explain how your evidence will be relevant to determining the relationships between patterns of activity of air masses and changes in weather conditions. Record your plan in your Science Notebook. Carry out your investigation.



Forecasting The most accurate and detailed forecasts are short term because weather systems change directions, speeds, and intensities over time. However, these forecasts are still only able to be predicted probabilistically. Because it is impossible for computers to model all of the different variables that affect the weather at a given time and place, long-term forecasts are even less reliable than short-term forecasts. Recall that features on Earth's surface, such as lakes or snow cover, affect the amount of thermal energy absorbed at any location. This affects the pressure at that location, which, in turn, affects the wind. Wind influences cloud formation and virtually all other aspects of the weather in that location. Over time, these factors interact and create more complicated weather scenarios.



THREE-DIMENSIONAL THINKING

Construct an explanation on whether a 30-day forecast will ever be accurate. Explain your reasoning.



 **GO ONLINE** for additional opportunities to explore!

Investigate how weather changes by performing one of the following activities.

Interpret a weather map to predict how weather will change at a given location in the **Investigation** *Weather*.

OR **Create** and use your own weather instruments in the **Lab** *How can you collect weather data and predict the weather?*

COLLECT EVIDENCE

How do meteorologists predict the weather? Record your evidence (E) in the chart at the beginning of the lesson.

A Closer Look: Doppler Radar

Meteorologists have many tools available to help them prepare weather forecasts. Accurate forecasts are important for giving people time to prepare for severe weather. With enough time, people can evacuate, find shelter, and take other measures to protect themselves. One of the newer tools for tracking and forecasting severe weather is Doppler radar.

What is Doppler radar?

The Doppler effect is an apparent shift in the observed frequency of a wave, due to the relative motion between the source and the observer. Radar stands for radio detection and ranging. Radar is used to measure precipitation when radio waves reflect off raindrops and snowflakes. Doppler radar is a specialized type of radar that can detect precipitation as well as the movement of small particles.

Doppler radar uses the Doppler effect to measure a target's velocity relative to the radar—the radar transmitter is the observer. This effect raises or lowers the frequency of the target echoes, depending on whether the target is moving toward or away from the radar. The difference between the radar's transmitted frequency and the reflected echoes of the target is a measure of the relative speed of the radar and target.

Doppler radar can effectively image the precipitation in a thunderstorm from the reflection of the water droplets in the system. It can also determine its motion—how fast the rain or hail is moving toward or away from the transmitter. Since the 1980s, computer programs have been developed to enable Doppler radar to identify hail, heavy rain, severe downdrafts, and tornadoes forming on the ground.



It's Your Turn

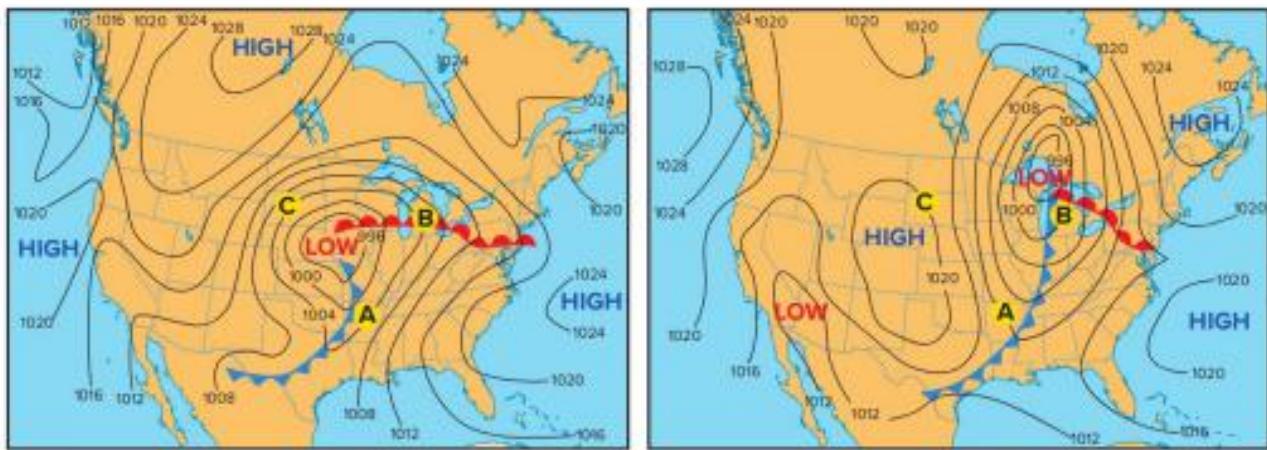
Infer How might a meteorologist tell the difference between the Doppler echo of a weather system and of a flock of migrating geese? Share your reasoning in the form of a news report.

LESSON 3

Review

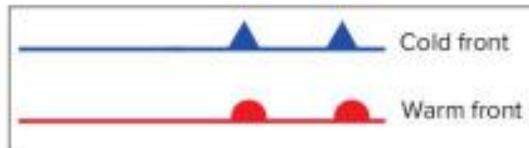
Summarize It!

Examine the weather maps below.



Day 1

Day 2



1. For each location, A, B, and C, describe how the weather changed over the two days.

2. Weather patterns generally move from west to east. Choose location A, B, or C and predict the weather on the third day for that location. Explain your reasoning in your Science Notebook.



Three-Dimensional Thinking

Use the weather map to answer question 3.



3. An Arctic air mass is approaching Lake Huron. Identify how this mass will affect the weather in the area.

- A The area will experience high air pressure and clear skies.
- B The area will experience high air pressure and cloudy skies.
- C The area will experience low air pressure and clear skies.
- D The area will experience low air pressure and cloudy skies.

4. How will the weather change in an area if a cold air mass meets a warm air mass?

- A The humidity will rise.
- B Temperatures will suddenly drop.
- C Air pressure will increase.
- D Winds will shift to the south.

5. The weather forecast predicts a 10 percent chance of rain when you leave for school in the morning. However, at the end of your school day it's raining. What reasoning can you provide for why this error occurred?

- A A high pressure system moved into the area quickly.
- B A warm air mass and a cold air mass moved apart.
- C Weather forecasts can only be predicted hourly.
- D Weather forecasts can only be predicted probabilistically.

Real-World Connection

6. **Compare** Why does northwest Washington often have rainy weather and southwest Texas is typically dry?

7. **Explain** In the morning you hear a meteorologist forecast today's weather as sunny and warm. After school, it's raining. Why is weather so hard to predict?

Still have questions?

Go online to check your understanding about how weather changes.

REVISIT



Do you still agree with the students you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with those students now.

EXPLAIN THE PHENOMENON



Revisit your claim about what causes weather to change. Review the evidence you collected. Explain how your evidence supports your claim.

KEEP PLANNING

STEM Module Project Science Challenge

Now that you have learned about what causes weather to change, go to your Module Project to continue planning your model. Keep in mind that you want to explain the factors that influence changing weather patterns.



LESSON 4 LAUNCH

Is it a model?



Two friends argued about how to describe maps. This is what they said:

Deanna: I think maps are types of models.

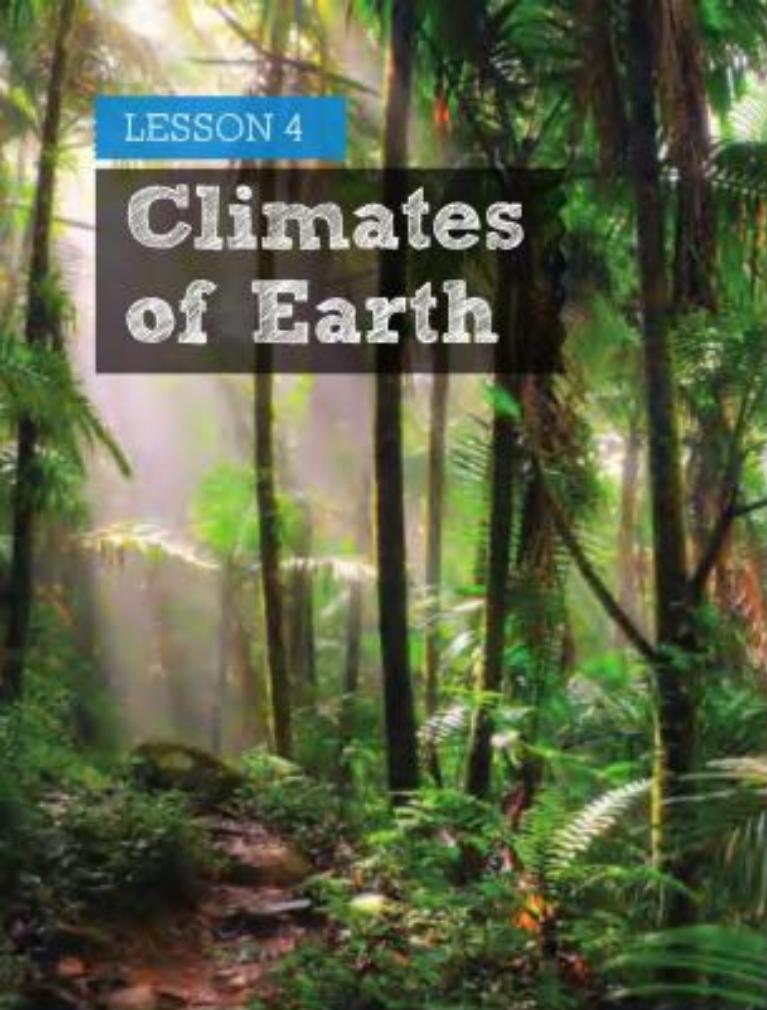
Morris: Maps aren't models; they are types of pictures.

Which person do you agree with the most? _____

Explain your ideas about maps.

You will revisit your response to the Science Probe at the end of the lesson.

Climates of Earth



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ENCOUNTER THE PHENOMENON

Why is one climate different from another?

Examine the photographs shown on the opposite page. With a partner, compare and contrast each location. What sort of average weather do you think each location receives? Give at least one factor that you think might influence the climate in each location. Write your ideas in the boxes below.

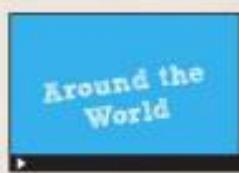


El Yunque National Forest, Puerto Rico

European Alps

Death Valley, California

Tuscany, Italy



GO ONLINE

Watch the video *Around the World* to see this phenomenon in action.

EXPLAIN THE PHENOMENON

Did you start to get some ideas about the factors that might cause the various locations to have such different climates? Use your ideas about the phenomenon to make a claim about why climates differ around the world.

CLAIM

Climates of Earth are different because...

COLLECT EVIDENCE

as you work through the lesson.

Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain how the distribution of solar energy affects climate?

B. What evidence have you discovered to explain how mountains affect climate?

MORE EVIDENCE

C. What evidence have you discovered to explain how oceans affect climate?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

Climates of Earth are different because...

D. What evidence have you discovered to explain why some regions are deserts and others are rain forests?

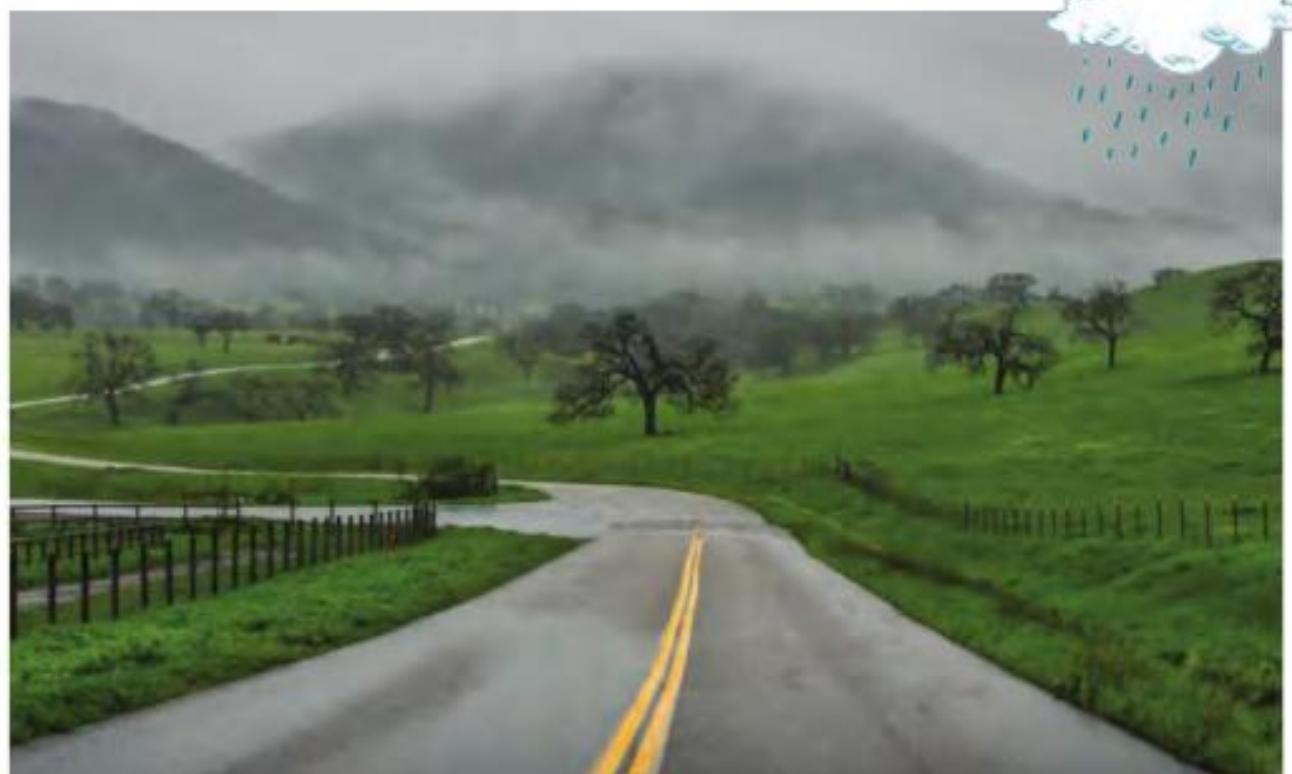
Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

What is climate?

You learned in the previous lesson that weather is the condition of the atmosphere at a particular place and time. It includes factors such as temperature, rainfall, and wind speed and direction. **Climate** refers to the average weather in a region over a long period of time. When you describe a morning as cool, rainy, and windy, you're talking about the weather. When you say that your city typically has mild winters with little snow, you're talking about the climate. Several factors determine a region's climate. It is the variation of these factors around the world that contribute to Earth's wide range of climates.



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Getty Images News/Catry Images



THREE-DIMENSIONAL THINKING

What is the relationship between weather **patterns** and climate?



Want more information?

Go online to read more about the factors that influence weather and regional climates on Earth.

FOLDABLES

Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

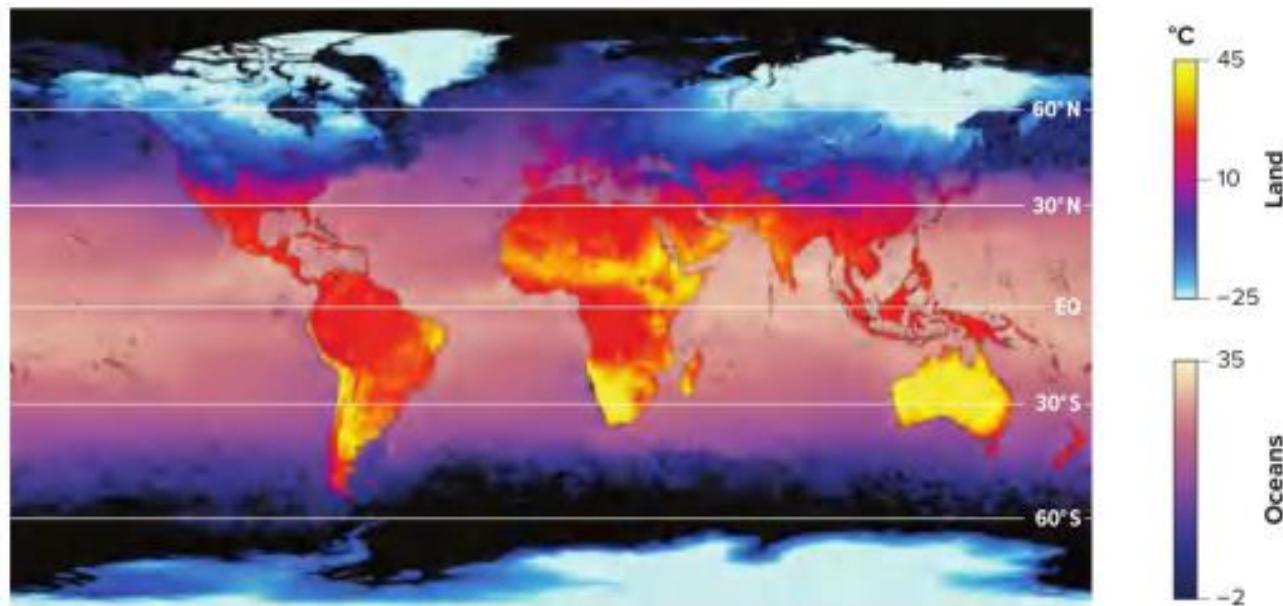
What is the most important influence on climate?

Several significant patterns can be identified by analyzing a world map of average temperatures. In the following activity, you will identify these patterns and describe why they occur using what you've learned so far in the module.

INVESTIGATION

Takin' the Temp of Earth

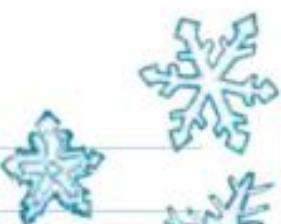
Examine the map below. Land surface temperature is a measure of how warm the Earth's surface would feel to the touch. Sea surface temperature is measured from the top millimeter of the ocean's surface. Take a moment to think about any general patterns that you see. Then answer the questions that follow.



Copyright © McGraw-Hill Education. Images from NASA's Earth Observatory Room.

1. Where are the warmest temperatures on Earth located?

2. Where are the coolest temperatures located?



3. What explains this general pattern?

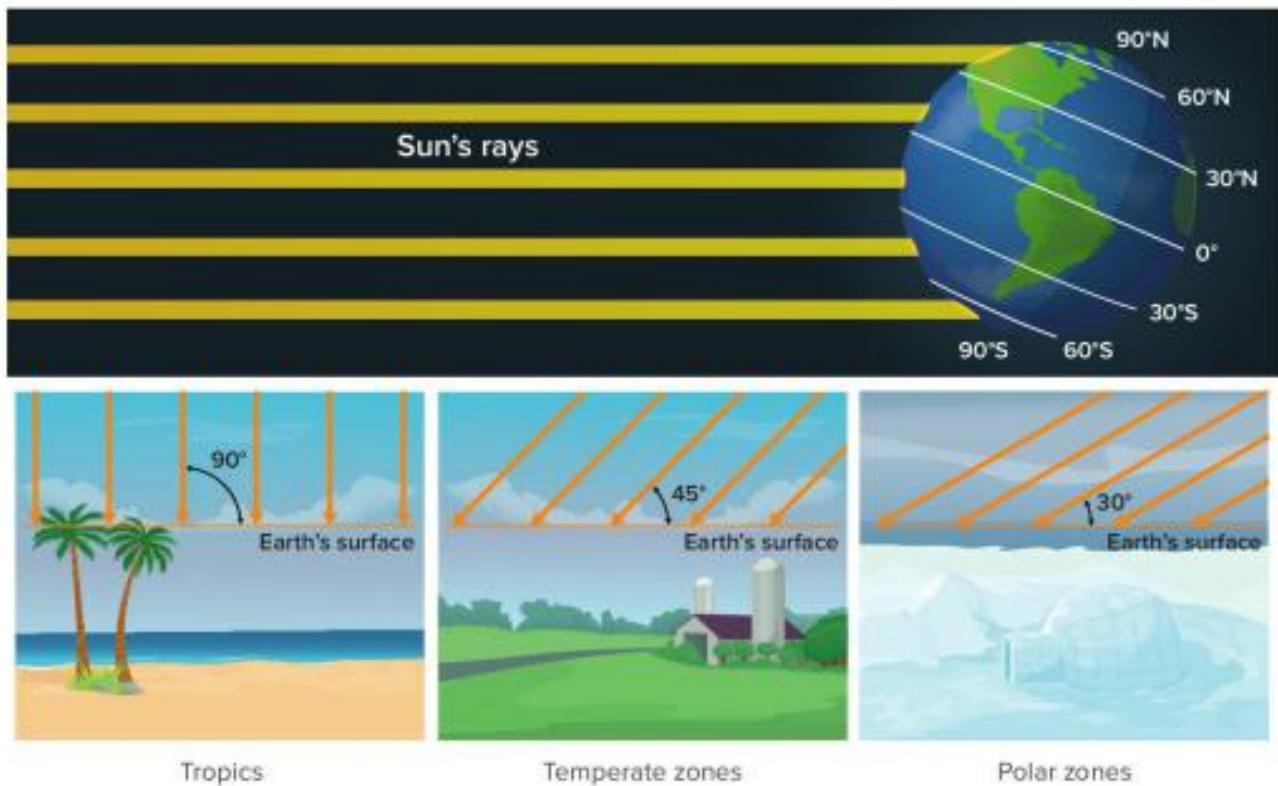


4. Is the temperature range (highest to lowest) greater for land or the oceans? Why do you think this occurs?

5. How might ice and snow in the polar regions contribute to the climate there?

6. Make a claim about the most influential factor on climate. What evidence from the investigation supports your claim?



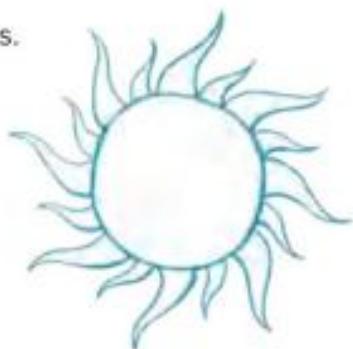


Solar Energy on Earth You just determined that the Sun is the most important influence on climate. Recall that because Earth is a sphere, different areas receive different amounts of solar energy. As a result, locations near the equator tend to have warmer climates than locations at higher latitudes.

Polar regions are colder because annually they receive less solar energy per unit of surface area. The snow and ice in these regions also contribute to the climate. Recall that ice has a very high albedo and reflects 75 to 90 percent of the solar energy it receives.

In the middle latitudes, between 30° and 60°, summers are generally hot and winters are usually cold. Thus, latitude—the distance north or south of the equator—largely determines the climate of most regions.

Additionally, when exposed to a similar amount of solar energy, the soil and rocks of the land warm to higher temperatures than the oceans. This means that temperatures are more extreme on continents and vary over a smaller range in the oceans.



COLLECT EVIDENCE

How does the distribution of solar energy affect climate? Record your evidence (A) in the chart at the beginning of the lesson.

Life at the Top
of the World

Average temperatures on Earth are increasing; sea ice is melting and disrupting entire ecosystems, which could threaten the survival of polar bears.

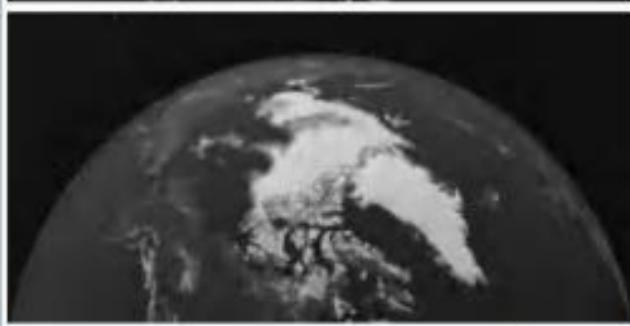
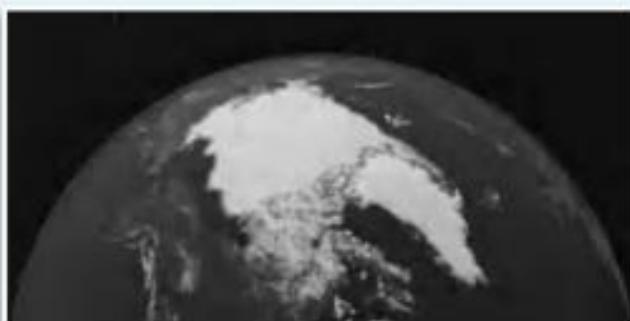
Life isn't easy when you're living at the top of the world in the vast, icy region known as the Arctic. It's so cold that ice covers parts of the Arctic Ocean all year long. However, a variety of species thrive in this polar climate. In fact, many ecosystems depend on the Arctic's ice for survival.

But as Earth's average temperatures increase, ice in the Arctic is melting. This includes sea ice—the ice that forms in an ocean. Sea ice follows a natural cycle in the Arctic. It spreads across the Arctic Ocean in winter then decreases in area during summer. But with rising temperatures, sea ice forms later and melts earlier each year. Over the last few decades, the amount of ice in the Arctic has decreased dramatically.

The disappearing ice is threatening the Arctic's top predator, the polar bear. Polar bears travel across sea ice to hunt for seals. As sea ice breaks up and melts, polar bears must swim longer distances to find prey. Also, late freezes and early thaws of sea ice mean shorter hunting seasons for them. Polar bears have been classified as a threatened species because their numbers are decreasing. If warming continues, they could become extinct.

The future of Arctic life is uncertain. Scientists continue to monitor climate data to understand the impact of increasing average temperatures on Arctic ecosystems. But, as Earth's climate continues to warm, life in the Arctic has to adjust to the changing conditions.

▼ Scientists use satellite images to monitor the amount of Arctic sea ice. These 1979 (top) and 2016 (bottom) images show that the area covered by summer sea ice is about half of what it was over 35 years ago.



It's Your Turn

ENVIRONMENTAL Connection How is climate change affecting other animals in the Arctic? Select an Arctic species and write a paragraph describing how it is, or isn't, adapting to climate change.

◀ Polar bears are aggressive hunters both on land and at sea. They can swim 100 km (60 miles) in search of prey. A thick layer of fat keeps the bear warm in the icy water.

How do mountains affect climate?

Latitude isn't the only factor that determines climate. Mountains across the globe create unique climate patterns. Let's investigate!

INVESTIGATION

In the Air

Study the map below. Compare the average temperatures of two cities in Colorado.



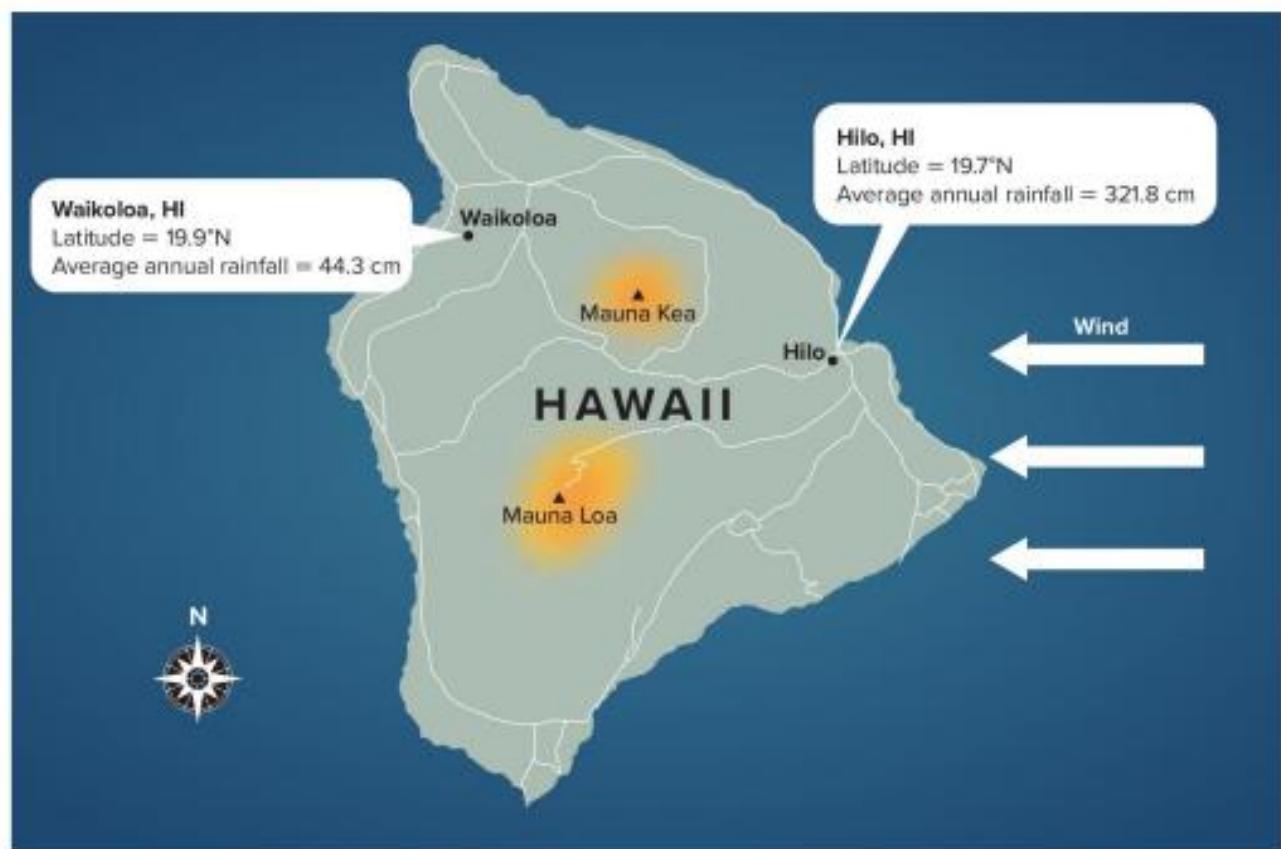
1. Which city has a cooler climate? What evidence supports your conclusion?

2. Is the difference between Leadville's and Burlington's climate related to their latitude? Explain your reasoning.

3. What effect does elevation have on temperatures? Use evidence in your explanation.

4. Why do you think this phenomenon occurs? Write or illustrate your ideas below.

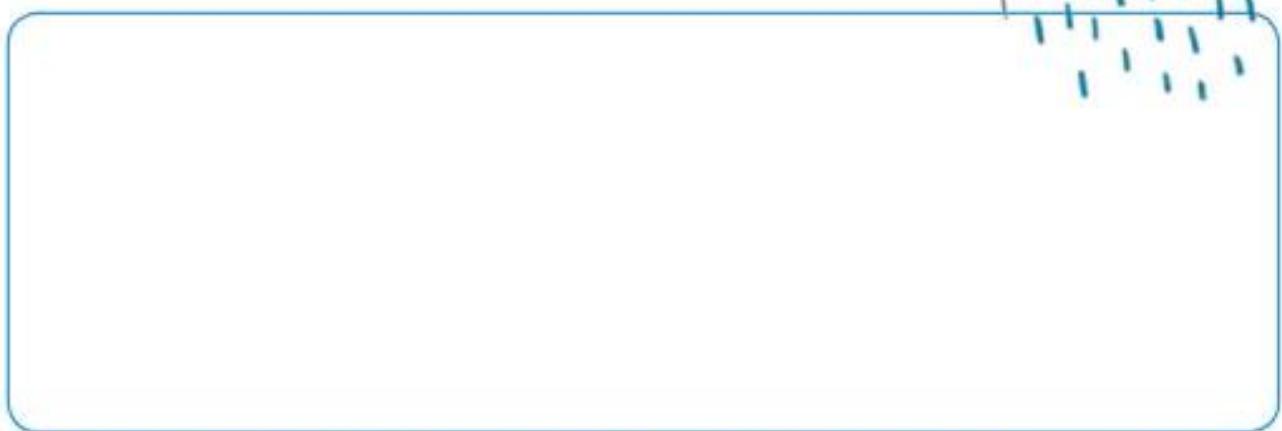
Next, analyze the map of Hawaii below. Compare the average precipitation of Waikoloa and Hilo.



5. In which direction does the wind blow over the volcanic mountains Mauna Kea and Mauna Loa?

6. Which city receives less rain? Why do you think this occurs?

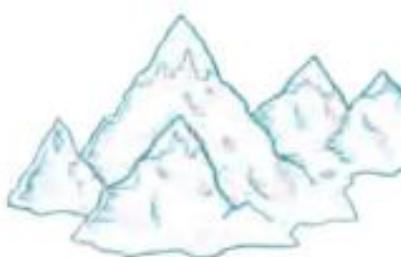
Write or illustrate your ideas below.



PHYSICAL SCIENCE Connection As you discovered, climate is influenced by mountains. The molecules that make up atmospheric gases are fewer and fewer in number as you go higher in altitude. This means that air pressure decreases with altitude. Given the same amount of thermal energy, air at lower pressures will have lower temperatures than air at higher pressures. Thus, mountain climates are usually cooler than those at sea level.

Rain Shadows Mountains also influence climate because they are barriers to prevailing winds. This leads to unique precipitation patterns called **rain shadows**—areas of low rainfall on the downwind slopes of mountains. Why does this phenomenon occur? When air rises over a mountain, the air expands and its temperature decreases, causing water vapor to condense and form rain. The climate on this side of the mountain—the windward side—is usually wet and cool. On the opposite side of the mountain—the leeward side—the air is drier and it warms as it descends. For this reason, deserts are common on the leeward sides of mountains.

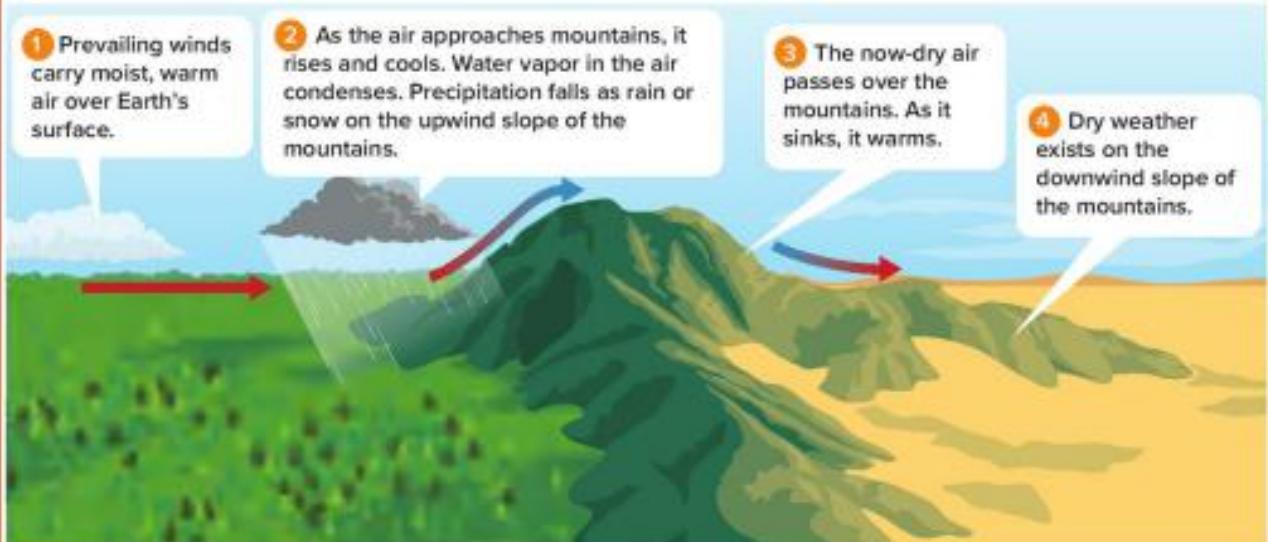
LIFE SCIENCE Connection Different amounts of precipitation on either side of a mountain range influence the types of vegetation that grow. Abundant amounts of vegetation grow on the side of the mountain exposed to the precipitation. The amount of vegetation on the leeward side is sparse due to the dry weather.





THREE-DIMENSIONAL THINKING

Examine the diagram below. Then answer the questions that follow.



1. What are the components of the **system**? Include inputs and outputs of the system.

2. Use the **model** to describe why rain shadows form on the leeward sides of mountains.

COLLECT EVIDENCE

How do mountains affect climate? Record your evidence (B) in the chart at the beginning of the lesson.

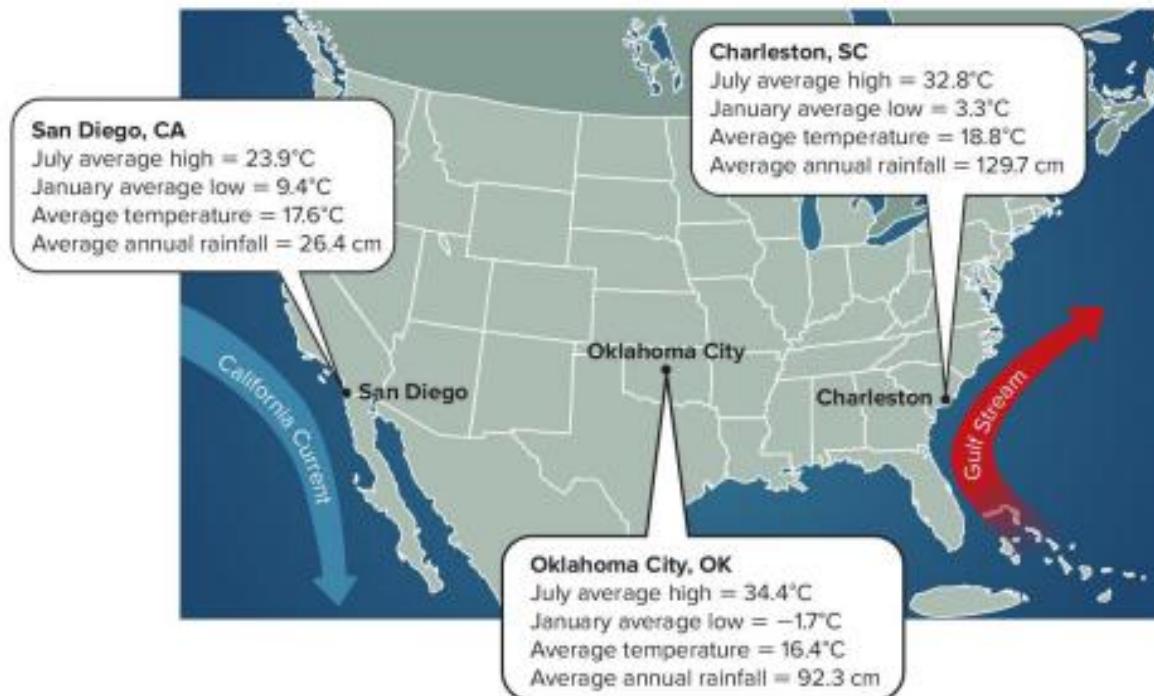
How do oceans affect temperatures and precipitation on land?

You've learned that latitude, altitude, and rain shadows influence climate. How does nearness to large bodies of water, such as oceans and lakes, as well as the temperature of ocean currents influence climate? Analyze the map below to find out.

INVESTIGATION

A Tale of Three Cities

Take a look at the map below. The California Current is a cold-water current. The Gulf Stream is a warm-water current. Analyze the temperature and precipitation data and then answer the questions that follow.



1. Which city experiences the largest range of temperatures? Brainstorm why this might occur.

2. Which coastal city is warmer? Which coastal city is cooler? Why do you think this occurs?



3. Which city receives the most rain? Why do you think this occurs?

4. Make a claim on how oceans affect climate. Use evidence from the investigation to support your reasoning.



Large Bodies of Water You just learned that continental areas tend to experience more extreme temperature ranges than coastal areas. Along coastlines, weather is more constant throughout the year. Why does this phenomenon occur?

PHYSICAL SCIENCE Connection Recall that water has a higher specific heat than the rocks and soil of the surrounding land. A high specific heat means that it takes much more thermal energy to raise the temperature of water than it does to raise the temperature of rocks and soil. Large bodies of water, therefore, will affect the climate of an area in several ways. Because a large body of water tends to heat slowly, the climate in the area is more moderate in the summer. In winter, the warmed water releases heat slowly, so the area around the body of water or in coastal areas is less cold than inland areas. Areas of land that are not near large lakes or an ocean are generally warmer in the summer and cooler in the winter than the areas near water.



Why does Azenhas do Mar, Portugal, have a moderate climate?

Ocean Currents Recall that solar energy drives convection in the oceans causing warm- and cold-water currents. The temperature of surface currents, combined with the prevailing winds, affects weather and climate in different ways. Regions near warm-water currents are often warmer and wetter than regions near cold-water currents. When water from the ocean is warmed by the Sun and evaporates, it releases moisture into the atmosphere. This increases the temperature and humidity of the surrounding air which forms rain and storms. These storms are carried by winds to different locations. Cold ocean currents make surrounding areas cooler and drier.



COLLECT EVIDENCE

How do oceans and other large bodies of water influence climate?

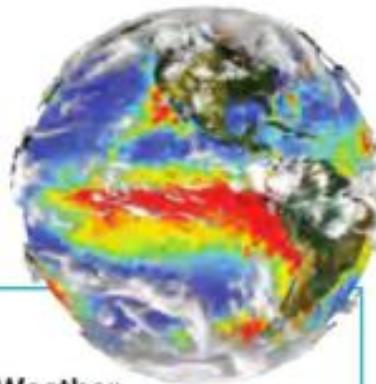
Record your evidence (C) in the chart at the beginning of the lesson.

Read a Scientific Text

A phenomenon, called El Niño, shows the connection between the atmosphere and the ocean. During an El Niño, climate changes can be seen around the world.

CLOSE READING

PRIMARY SOURCE



Pacific Wind and Current Changes Bring Warm, Wild Weather

If you want to understand how interconnected our planet is—how patterns and events in one place can affect life half a world away—study El Niño.

During an El Niño event, the surface waters in the central and eastern Pacific Ocean become significantly warmer than usual. That change is intimately tied to the atmosphere and to the winds blowing over the vast Pacific. Easterly trade winds (which blow from the Americas toward Asia) falter and can even turn around into westerlies. This allows great masses of warm water to slosh from the western Pacific toward the Americas. It also reduces the upwelling of cooler, nutrient-rich waters from the deep—shutting down or reversing ocean currents along the equator and along the west coast of South and Central America. We know these large-scale shifts in Pacific winds and waters initiate El Niño. What we don't know is what triggers the shift. This remains a scientific mystery.

What is not a mystery is that El Niño is one of the most important weather-producing phenomena on Earth. The changing ocean conditions disrupt weather patterns and marine fisheries along the west coasts of the Americas. Dry regions of Peru, Chile, Mexico, and the southwestern United States are often deluged with rain and snow, and barren deserts have been known to explode in flowers. Meanwhile, wetter regions of the Brazilian Amazon and the northeastern United States often plunge into months-long droughts.

El Niño events occur roughly every two to seven years, as the warm cycle alternates irregularly with its sibling La Niña—a cooling pattern in the eastern Pacific—and with neutral conditions.

Source: National Aeronautics and Space Administration

Copyright © McGraw-Hill Education. (Photo: B. Blum/NASA/GSFC/NASA SCIENCE PHOTO LIBRARY/Getty Images; Traci Tokaric, Mike and Stephanie Schillaci, U.S. "El Niño Pacific Wind and Current Changes Bring Warm, Wild Weather." Feature Article." NASA. <https://earthobservatory.nasa.gov/Features/ENinow/>

Inspect

Read the passage *Pacific Wind and Current Changes Bring Warm, Wild Weather*.

Find Evidence

Reread the second paragraph. Highlight the relationships among events that can be described as a cause-and-effect relationship.

Make Connections

Collaborate With your partner, discuss how changes in Earth's atmospheric circulation can cause changes in Earth's oceanic circulation and the stability of climate patterns. Has El Niño affected weather or climate where you live?

 **GO ONLINE** for an additional opportunity to explore!

Want to learn about El Niño's counterpart, La Niña? Perform the following activity!

Analyze temperature change during a La Niña event in the **Investigation** *How does La Niña affect climate?*

Why do some regions have rain forests and others deserts?

Some of the world's most extreme climates are rain forests and deserts. A forest with high annual rainfall, no freezing temperatures, and a rich collection of plant and animal life is a rain forest. Rain forests comprise only 2 percent of Earth's land surface, yet hold nearly half of terrestrial life. Deserts are dry lands that cover many parts of Earth's land. Vegetation is sparse in deserts, commonly covering less than 15 percent of the ground. What controls the location of rain forests and deserts?

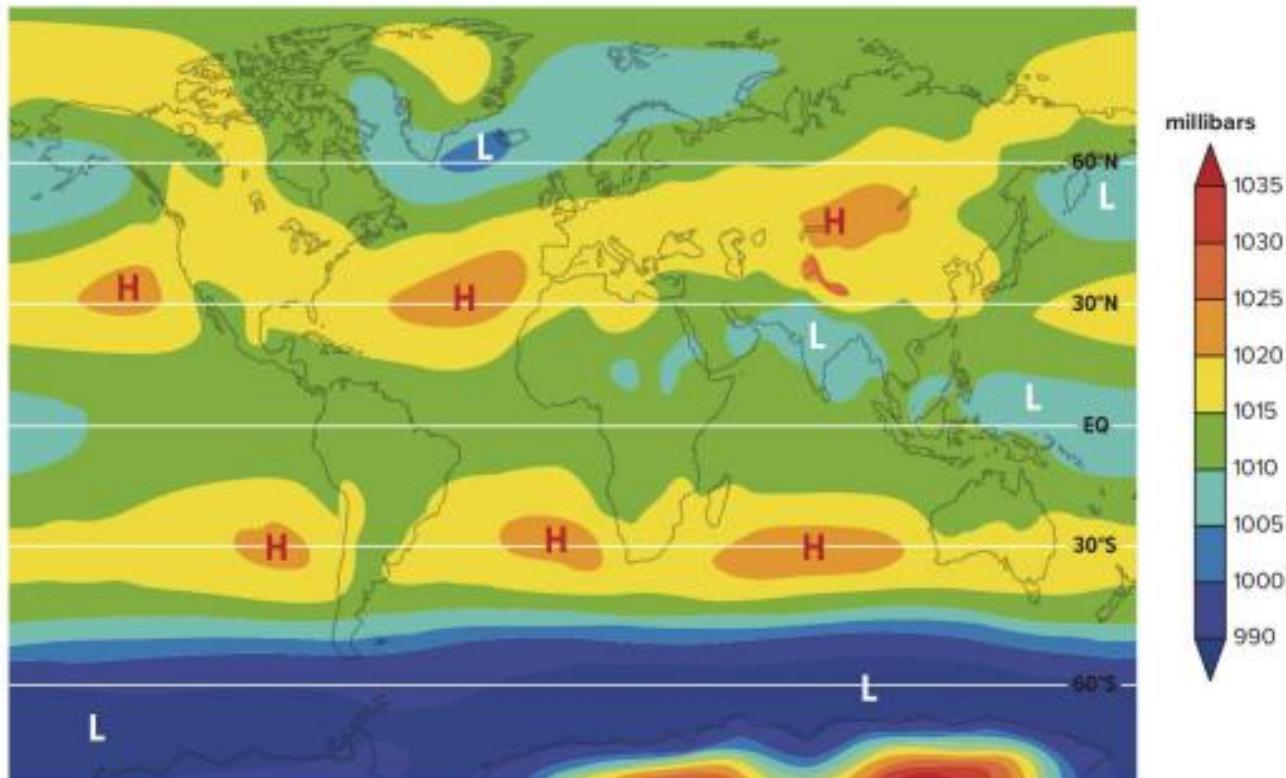


INVESTIGATION

Patterns of Precipitation

Examine the air pressure map below.

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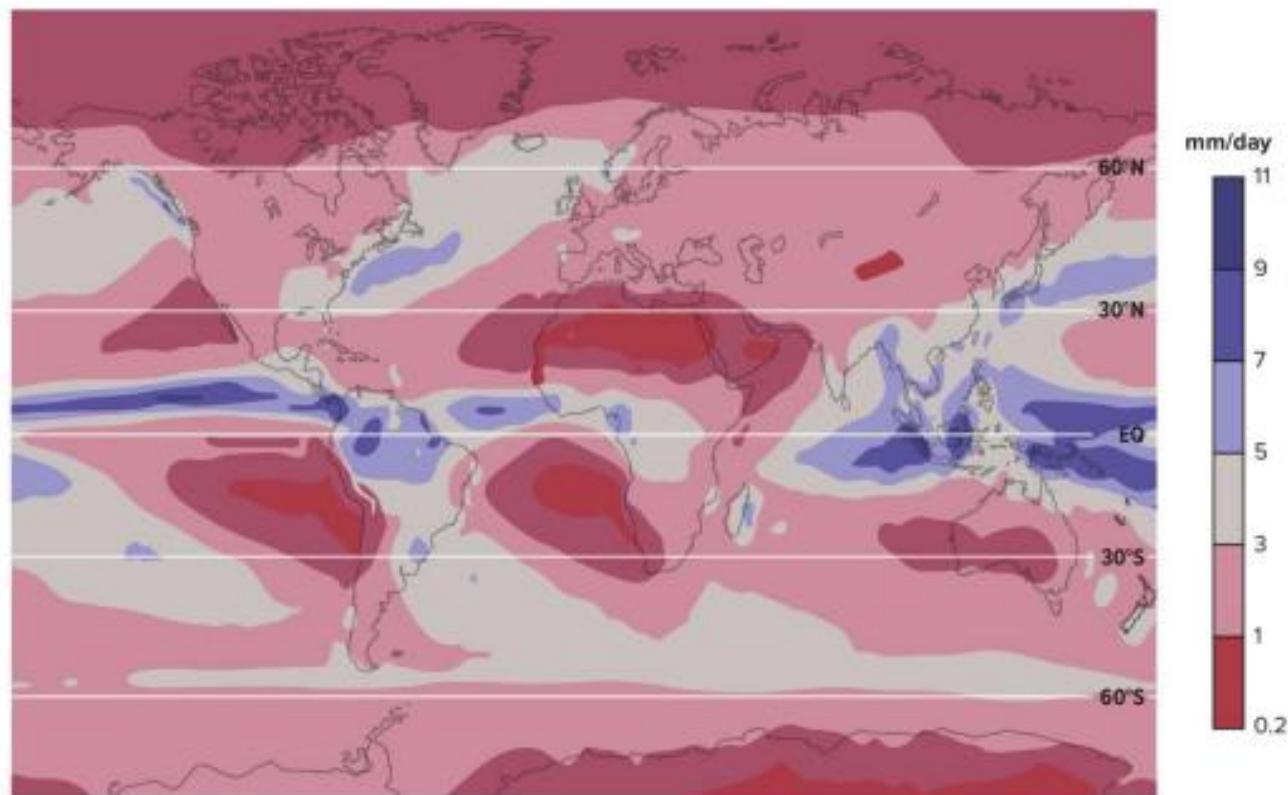


1. At what latitudes do you find the high pressure systems?

2. At what latitudes do you find the low pressure systems?



Next, review the precipitation map. Blue represents more precipitation. Red indicates less.



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3. At what latitudes do you find the highest precipitation rates?

4. At what latitudes do you find the lowest precipitation rates?

Finally, examine the map of the locations of major deserts and rain forests.



5. Where do most deserts occur? Where do most rain forests occur?

6. Compare the three maps. What patterns do you notice between the locations of Earth's major deserts and rain forests and the precipitation and pressure patterns? Explain these patterns in terms of pressure systems and precipitation.



Precipitation and Pressure Systems Recall that high-pressure systems are associated with sinking, dry air. Low-pressure systems are associated with rising, moist air. As you just investigated, the result is a pattern of drier weather and climates near latitudes with high-pressure zones and wetter weather and climates near latitudes with low-pressure zones.

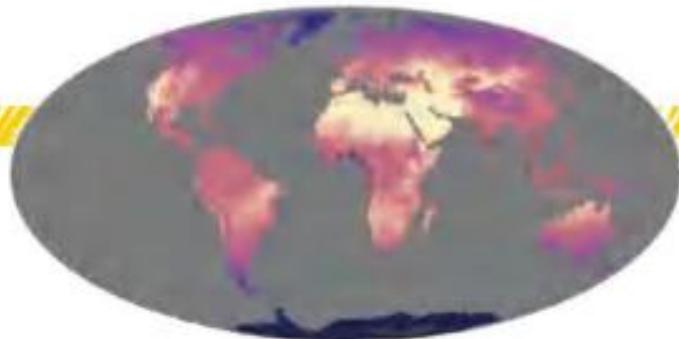
While the amount of precipitation a region receives largely determines the locations of rain forests and deserts, the plants (or lack thereof) also affect climate and weather. As you watch the animation below, see if you notice any patterns.

INVESTIGATION

Patterns of Plant Growth

 **GO ONLINE** to explore the video *Vegetation and Land Surface Temperature*.

Describe the patterns you observe in the video.



Land Surface Temperature (daytime)
°C
25 10 45



Vegetation Index (NDVI)
-0.1 0.4 0.9

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Observatory (NEO)

LIFE SCIENCE Connection

Vegetation impacts weather and climate. Plants absorb solar energy, keeping the land relatively cool. Plants also release water vapor through transpiration into the atmosphere, contributing to cloud formation.

COLLECT EVIDENCE

Why are some regions rain forests while others are deserts? Record your evidence (D) in the chart at the beginning of the lesson.

How are climates classified?

As you've discovered, the world has many climates that range from polar to tropical. In 1918, German scientist Wladimir Köppen developed a system for classifying the world's many climates. Köppen classified a region's climate by studying its average monthly temperatures, precipitation, and native vegetation. Köppen classified climates into five main types: polar, continental, dry, tropical, or mild.



THREE-DIMENSIONAL THINKING

Examine the map showing a modified version of Köppen's climate classification system. Using the map, identify the climate of each of the locations from the activity at the beginning of the lesson. Then, **construct an explanation** based on evidence of the factors that determined each location's climate in your Science Notebook.

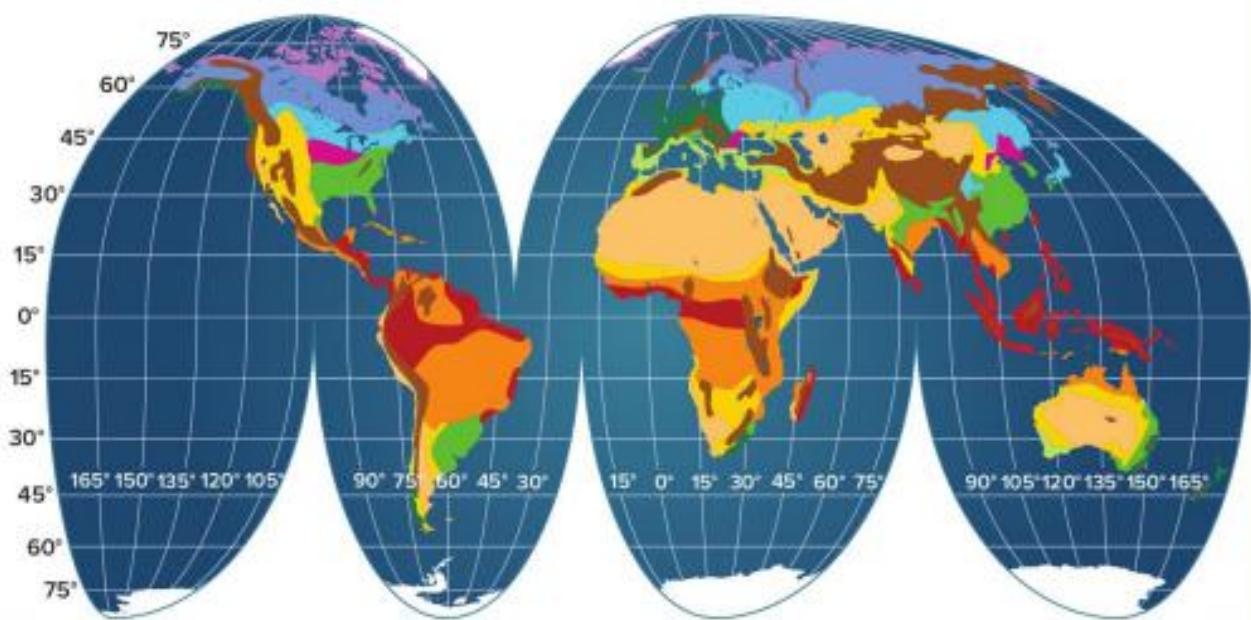
El Yunque National Forest, Puerto Rico

European Alps

Death Valley, California

Tuscany, Italy

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Tropical climates

- Tropical wet
- Tropical wet and dry

Mild climates

- Mediterranean
- Humid subtropical
- Marine west coast

Dry climates

- Semiarid
- Arid

Continental climates

- Warm summer
- Cool summer
- Subarctic

Polar climates

- Tundra
- Ice cap
- Highland

Review

Summarize It!

1. **Organize** your understanding of the factors that affect weather and climate around the world using the chart below. The topic is *Factors Influencing Weather and Climate*. Choose four central ideas you learned about in this lesson and provide specific details about each main idea.

Topic: _____

Main Ideas

Specific Details



Three-Dimensional Thinking

One of the major currents in Pacific Ocean is the California Current. The California Current and its direction of flow are shown on this map.



2. Which weather and climate conditions are most likely to occur in the land areas near the California Current as compared to the land areas near the Gulf Stream?
 - A cooler with more frequent rains
 - B cooler and relatively dry
 - C warmer with more frequent rains
 - D warmer and relatively dry

3. Which statement accurately describes why the above phenomenon occurs?
 - A The California Current releases more thermal energy and moisture to the air.
 - B The California Current releases more thermal energy and less moisture to the air.
 - C The California Current releases less thermal energy and moisture to the air.
 - D The California Current releases less thermal energy and more moisture to the air.

Real-World Connection

4. **Predict** how the weather and climate of your town would change if North America and Asia moved together and became one enormous continent.

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 Still have questions?

Go online to check your understanding about climates of Earth.

REVISIT



Do you still agree with the person you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON



Revisit your claim about why climates on Earth differ. Review the evidence you collected about the causes of patterns of climates. Explain how your evidence supports your claim.

PLAN AND PRESENT

STEM Module Project Science Challenge

Now that you've learned about weather and climate patterns, go back to your Module Project to continue planning your model, build your model, and give your presentation. Your goal is to act like a climatologist and explain the factors that affect weather and climate.



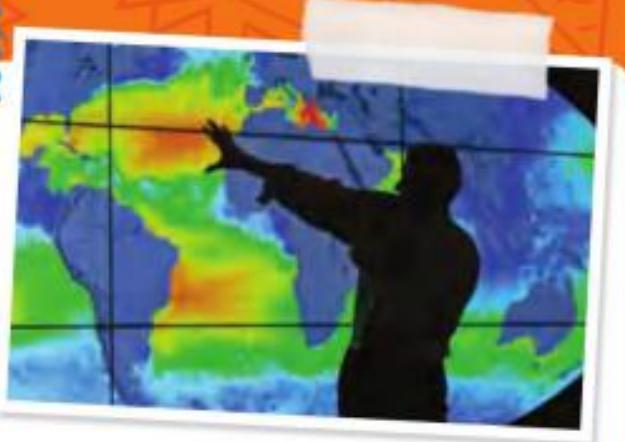


STEM Module Project

Science Challenge

As the Water Churns

You are a climatologist for the National Oceanic and Atmospheric Administration (NOAA). Your agency works with educators to help students understand weather and climate. You have been asked to develop a model for middle-school students to explain how patterns of atmospheric and oceanic circulation determine regional climates.



You will use your model to describe how the unequal heating and rotation of Earth cause the movement of air and water, and how these movements transfer thermal energy around the globe, ultimately affecting weather and climate.

Planning After Lesson 1

How does energy from the Sun reach Earth?

How will your model show how land, water, and air absorb and release thermal energy?



STEM Module Project

Science Challenge

Planning After Lesson 2

Sketch a globe below. Label the movement of prevailing winds and ocean currents. Highlight the prevailing winds and ocean currents that affect your area. Add a caption that explains how Earth's rotation and landforms affect the movement of air and water.

How will your model show the factors that affect the movement of global winds and ocean currents?

Planning After Lesson 3

Patterns of air and water movement have a major effect on local weather patterns. Look back at the data you collected in the *Predicting Weather* lab in Lesson 3. Use what you've learned about atmospheric and oceanic circulation to explain your weather data.

How do your weather data provide evidence for why local weather conditions change?



STEM Module Project

Science Challenge

Planning After Lesson 4

What factors affect climate?

How will you use your model to describe general patterns of climate?

Use what you've learned to identify the factors that affect your regional climate. How can you use your model to describe your climate?

Develop Your Model

Look at the planning you did after each lesson. Use that information to construct your model and prepare your presentation. Test your model several times, making modifications as needed. Keep in mind that you want your model to show the role of different factors in producing regional climates and changes in weather.

Evaluate Your Model

Once you feel your model is ready to be presented, identify the model elements in the table below.

Model Elements	Descriptions
Components (What are the different parts of my model?)	
Relationships (How do the components of my model interact?)	
Connections (How does my model help me understand the phenomenon?)	



STEM Module Project

Science Challenge

Create Your Presentation

Analyze your model before presenting it to the class.

What type of model (e.g. computer, physical, pictorial) did you develop for this Science Challenge? Why did you choose this type of model?

Why is it important to test your model several times before presenting it to a class of students? What modifications did you make to ensure the best design?

In an earlier lab, you predicted weather. Can you use your model to predict changing weather conditions? Why or why not?

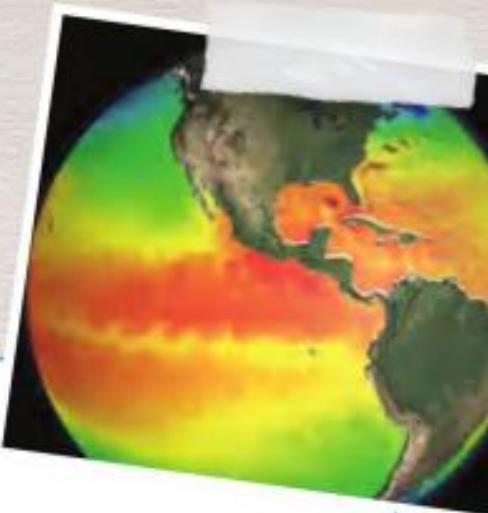
What other components (such as video, audio, or images) might you include in your presentation? Decide how you will present your model to the class. Give your presentation.

Congratulations!
You've completed the
Science Challenge
requirements!

Module Wrap-Up

REVISIT THE PHENOMENON

Using the model you developed for the Science Challenge, explain how water transfers heat around the globe, and how this transfer of thermal energy influences weather and climate.



OPEN INQUIRY

What are one or two questions you still have about the phenomenon?

Choose the question you are most interested in. Plan and conduct an investigation to answer this question.

Multilingual Glossary

 **GO ONLINE** to find multilingual glossaries for science.
The glossaries include the following languages.

Arabic	Korean	Tagalog
Bengali	Mandarin Chinese	Urdu
French	Portuguese	Vietnamese
Haitian Creole	Russian	
Hmong	Spanish	

Cómo usar el glosario en español:

1. Busca el término en inglés que deseas encontrar.
2. El término en español, junto con la definición, se encuentran en la columna de la derecha.

Pronunciation Key

Use the following key to help you sound out words in the glossary.

a	back (BAK)	éw	food (FEWD)
ay	day (DAY)	yoo	pure (PYOOR)
ah	father (FAH thur)	yew	few (FYEW)
ow	flower (FLOW ur)	uh	comma (CAH muh)
ar	car (CAR)	u (+ con)	rub (RUB)
E	less (LES)	sh	shelf (SHELF)
ee	leaf (LEEF)	ch	nature (NAY chur)
ih	trip (TRIHP)	g	gift (GIHFT)
i (i + com + e)	idea (i DEE uh)	j	gem (JEM)
oh	go (GOH)	ing	sing (SING)
aw	soft (SAWFT)	zh	vision (VIH zhun)
or	orbit (OR buhrt)	k	cake (KAYK)
oy	coin (COYN)	s	seed, cent (SEED)
oo	foot (FOOT)	z	zone, raise (ZOHN)

English

air mass/conduction

air mass: a large area of air that has uniform temperature, humidity, and pressure.

albedo: the measure of the reflectivity of a surface.

aquifer: an area of permeable sediment or rock that holds significant amounts of water.

climate: the long-term average weather conditions that occur in a particular region.

closed system: a system that does not exchange matter or energy with the environment.

condensation: the process by which a gas changes to a liquid.

conduction: the transfer of thermal energy by collisions between particles of matter.

A

Español

masa de aire/conducción

masa de aire: gran área de aire que tiene temperatura, humedad y presión uniformes.

albedo: medida del reflectividad de una superficie.

acuífero: área de sedimento permeable o roca que conserva cantidades significativas de agua.

C

clima: promedio a largo plazo de las condiciones del tiempo atmosférico de una región en particular.

sistema cerrado: sistema que no intercambia materia o energía con el ambiente.

condensación: proceso mediante el cual un gas cambia a líquido.

conducción: transferencia de energía térmica debido a colisiones entre partículas.

convection/precipitation

convection: the transfer of thermal energy by the movement of particles from one part of a material to another; the circulation of particles within a material caused by differences in thermal energy and density.

Coriolis effect: the movement of wind and water to the right or left that is caused by Earth's rotation.

crystallization: the process by which atoms form a solid with an orderly, repeating pattern.

convección/precipitación

convección: transferencia de energía térmica por el movimiento de partículas de una parte de la materia a otra; circulación de partículas en el interior de un material causada por diferencias en la energía térmica y la densidad.

efecto Coriolis: movimiento del viento y del agua a la derecha o a la izquierda causado por la rotación de la Tierra.

cristalización: proceso mediante el cual los átomos forman un sólido con un patrón ordenado y repetitivo.

D

density current: the vertical movement of water caused by differences in density.

diffusion: the movement of substances from an area of higher concentration to an area of lower concentration.

corriente de densidad: movimiento vertical de agua causado por las diferentes densidades.

difusión: movimiento de sustancias de un área de mayor concentración a un área de menor concentración.

E

evaporation: the process of a liquid changing to a gas at the surface of the liquid.

evaporación: proceso por el cual un líquido cambia a gas en la superficie de dicho líquido.

F

front: a boundary between two air masses.

frente: límite entre dos masas de aire.

H

heat: the transfer of thermal energy from a region of higher temperature to a region of lower temperature. Heat can also refer to the amount of energy transferred during this process.

calentar: transferencia de energía térmica desde una región de temperatura más alta a otra región de temperatura más baja.

calor: cantidad de energía transferida durante este proceso.

K

kinetic (kuh NEH tik) energy: energy due to motion.

energía cinética: energía debida al movimiento.

L

latitude: the distance in degrees north or south of the equator.

latitud: distancia en grados al norte o al sur del Ecuador.

O

open system: a system that exchanges matter or energy with the environment.

sistema abierto: sistema que intercambia materia o energía con el ambiente.

P

polar easterlies: cold winds that blow from the east to the west near the North Pole and South Pole.

brisas polares: vientos fríos que soplan del este al oeste cerca del Polo Norte y del Polo Sur.

potential (puh TEN chul) energy: stored energy due to the interactions between objects or particles.

energía potencial: energía almacenada debido a las interacciones entre objetos o partículas.

precipitation: water, in liquid or solid form, that falls from the atmosphere.

precipitación: agua, en forma líquida o sólida, que cae de la atmósfera.

prevailing westerlies: steady winds that flow from west to east between latitudes 30°N and 60°N, and 30°S and 60°S.

radiation: the transfer of thermal energy from one material to another by electromagnetic waves.

rain shadow: an area of low rainfall on the downwind slope of a mountain.

random motion: movement in all directions and at different speeds.

receiver object: the object that gains energy from the energy transfer.

source object: the object that provides energy for energy transfer.

specific heat: the amount of thermal energy it takes to increase the temperature of 1 kg of a material by 1°C.

surface current: a wind-driven current that carries ocean water horizontally across the ocean's surface.

temperature: the measure of the average kinetic energy of the particles in a material.

thermal conductor: a material through which thermal energy flows easily.

thermal contraction: a decrease in a material's volume when the temperature is decreased.

thermal energy: the result of the motion of all the particles, and the distance and attractions between those particles in the system.

thermal equilibrium: when the temperatures of materials that are in contact are the same.

thermal expansion: an increase in a material's volume when the temperature is increased.

thermal insulator: a material through which thermal energy does not flow easily.

thermodynamics: the study of heat.

trade winds: steady winds that flow from east to west between 30°N latitude and 30°S latitude.

transpiration: the process by which plants release water vapor through their leaves.

upwelling: the vertical movement of water toward the ocean's surface.

vientos del oeste: vientos constantes que soplan de oeste a este entre latitudes 30°N y 60°N, y 30°S y 60°S.

R

radiación: transferencia de la energía térmica de un material a otro por las ondas electromagnéticas.

sombra de lluvia: área de baja precipitación en la ladera de sotavento de una montaña.

movimiento aleatorio: movimiento en todas direcciones y a velocidades diferentes.

receptor de energía: objeto que recibe la energía en la transferencia de energía.

S

fuente de energía: objeto que provee la energía en la transferencia de energía.

calor específico: cantidad de energía térmica necesaria para aumentar la temperatura de 1 kg de un material en 1°C.

corriente superficial: corriente impulsada por el viento que lleva agua del océano horizontalmente por la superficie del océano.

T

temperatura: medida de la energía cinética promedio de las partículas de un material.

conductor térmico: material por el que fluye fácilmente la energía térmica.

contracción térmica: disminución del volumen de un material cuando disminuye la temperatura.

energía térmica: resultado del movimiento de todas las partículas, la distancia y las atracciones entre las partículas en el sistema.

equilibrio térmico: cuando los materiales que están en contacto tienen la misma temperatura.

expansión térmica: aumento en el volumen de un material cuando aumenta la temperatura.

aislante térmico: material por el que no fluye fácilmente la energía térmica.

termodinámica: estudio del calor.

vientos alisios: vientos constantes que soplan del este al oeste entre 30°N de latitud y 30°S de latitud.

transpiración: proceso por el cual las plantas liberan vapor de agua por medio de las hojas.

U

surgencia: movimiento vertical del agua hacia la superficie del océano.

V

vaporization: the change in state from a liquid to a gas.

vaporización: cambio de estado líquido a gaseoso.

W

water cycle: the series of natural processes by which water continually moves throughout the hydrosphere.

ciclo del agua: serie de procesos naturales por los que el agua se mueve continuamente en toda la hidrosfera.

weather: the atmospheric conditions, along with short-term changes, of a certain place at a certain time.

tiempo atmosférico: condiciones atmosféricas, junto con cambios a corto plazo, de un lugar determinado a una hora determinada.

wind: the movement of air from areas of high pressure to areas of low pressure.

viento: movimiento del aire desde áreas de alta presión hasta áreas de baja presión.

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Italic numbers = illustration/photo
Bold numbers = vocabulary term
lab = indicates entry is used in a lab
inv = indicates entry is used in an investigation
smp = indicates entry is used in a STEM Module Project
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