AmplifyScience

Thermal Energy:

Using Water to Heat a School

Investigation Notebook with Article Compilation

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UNIVERSITY OF CALIFORNIA, BERKELEY

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Thermal Energy:
Using Water to Heat a School

Investigation Notebook

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.
8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.
9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.
10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.
11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: ______________________________ Date: ________________

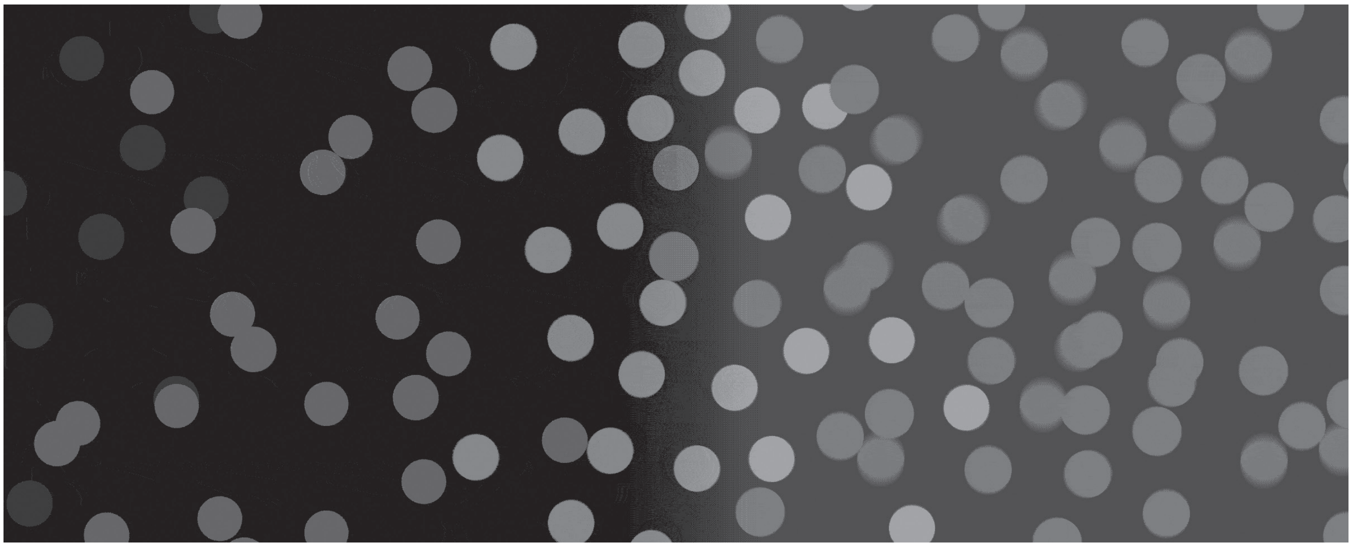
Thermal Energy: Using Water to Heat a School
Unit Overview

Temperature impacts many of the decisions we make every day. Whether you are choosing between a glass of cold lemonade and a cup of hot cocoa or deciding what to wear in the morning, temperature shapes the way we live our lives. But what is temperature? Why are some things hot and others cold? In this unit, you'll answer these questions and many more as you learn about thermal energy, the invisible but ever-present energy that helps us understand temperature.

Name: ____________________ Date: ____________

Chapter 1: Understanding Temperature
Chapter Overview

The principal of Riverdale School needs your help choosing between two heating systems for the school. To help him decide which option will work best, you will begin by investigating how things change when they are at different temperatures.



Name: ______________________________ Date: ________________

Lesson 1.2: Investigating Hot and Cold

Quick, name something hot! Did you think of fire? Now, name something cold! Did you think of ice? We're all familiar with things that are hot or cold, but what does it actually mean for something to be hot or cold? How is something different when it is warmer or cooler? In this lesson, you'll start gathering evidence to answer this question, which will help you in your new role of student thermal scientist as you try to decide what kind of heating system to recommend to Riverdale School.

Unit Question

- Why do things change temperature?

Chapter 1 Question

- What is happening when the air in the school gets warmer?

Vocabulary

- temperature

Name: ______________________ Date: ______________

Warm-Up

Anticipation Guide

Read each statement below and decide if you agree or disagree. (check one)

1. Temperature is the measurement of how hot or cold something is.

   ☐ agree ☐ disagree

2. When something heats up, it moves faster, and when something cools down, it moves slower.

   ☐ agree ☐ disagree

3. When something heats up, new energy is created, and when something cools down, energy is destroyed.

   ☐ agree ☐ disagree

4. Hotter things have more energy than colder things.

   ☐ agree ☐ disagree

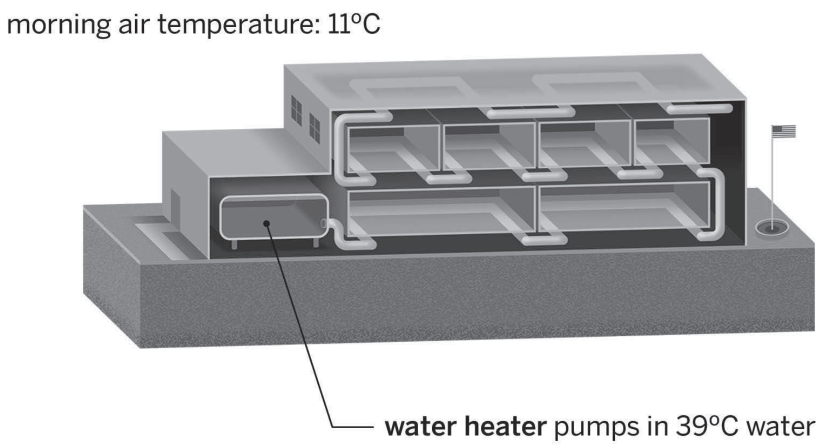
Name: ______________________________ Date: ____________________

Observing the Heating System Diagrams

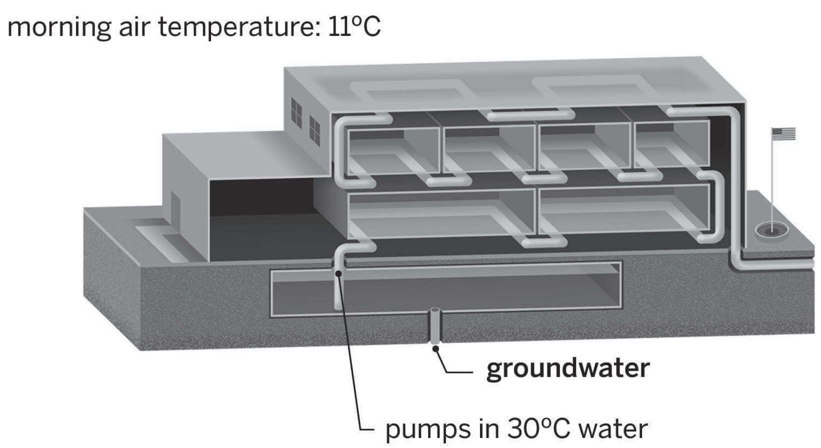
Look closely at the two diagrams below.
Discuss the following questions with your partner:

- How are the heating systems similar and how are they different?
- What questions do you have about how the heating systems work?
- Which heating system do you think will warm the school more during the winter? Why?

Proposal #1:
Water Heater System



Proposal #2:
Groundwater System



Name: ______________________________ Date: ____________________

Investigating Hot and Cold Things

Safety Note: Using Hot Water

Make sure the water is not hot enough to burn. Don't fill hot water to the top of the cup. Be careful around the hot water.

Investigating Hot and Cold

Follow these instructions to set up your investigation.

1. Carefully fill three-quarters of the cup labeled with a "C" with cold water.
2. Carefully fill three-quarters of the cup labeled with an "H" with hot water.
3. Place the thermometer in the cup of cold water, wait for 15 seconds, then record the temperature of the cold water below.
4. Place the thermometer in the cup of hot water, wait for 15 seconds, then record the temperature of the hot water below.
5. Make a prediction about what you will see when you add food coloring to each cup.

   The temperature of the cold water is __________. The temperature of the hot water is __________.

   I predict that when I add food coloring to the water in the cups, the food coloring will: (check one)

   - ☐ spread out faster in the cold water.
   - ☐ spread out faster in the hot water.
   - ☐ spread out equally fast in the cold and hot water.

6. Add 2 drops of food coloring to each plastic cup.
7. Observe what happens in the two plastic cups and record your observations below.

   How did the temperature of the water affect the movement of the food coloring?

   ____

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Name: ______________________________ Date: ________________

Reflecting on the Investigation

Today you worked on collecting evidence to answer the Investigation Question: *How is something different when it is warmer or cooler?*

How did the experiment with the cold and warm water change your thinking about the Investigation Question?

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Name: ______________________________ Date: ________________

Lesson 1.3: Temperature and Motion

We know that food coloring spreads through water even if it isn't stirred. Why? Is the water moving? We also know that food coloring spreads faster in hot water. Why is that? What's the difference between hot and cold water? In this lesson, you will use a digital Simulation to simulate your food coloring investigation from the previous lesson and to gather more evidence about how something is different when it is hot or cold.

Unit Question

- Why do things change temperature?

Chapter 1 Question

- What is happening when the air in the school gets warmer?

Vocabulary

- molecule
- temperature

Digital Tool

- *Thermal Energy* Simulation

Name: ______________________ Date: ______________

Warm-Up

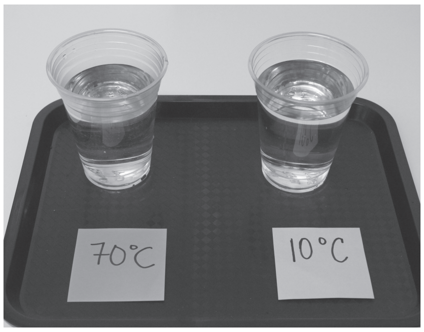
Launch the *Thermal Energy* Simulation.

1. Explore the Simulation on your own digital device. Investigate how the Simulation works and what you can change. Use the space below to record what you notice, if needed.
2. Discuss the following questions with your partner:
   - What are some things you can do in Run?
   - What are some things you can do in Analyze?

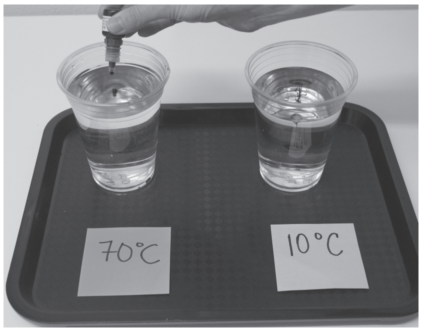
Name: ______________________________ Date: ________________

Simulating Hot and Cold Water

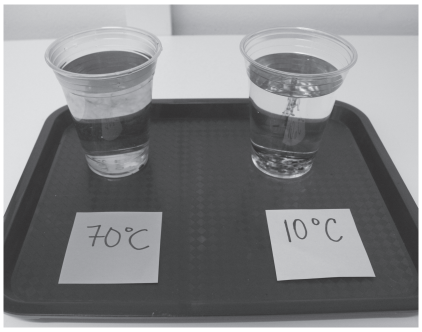
Use the *Thermal Energy* Simulation to recreate a similar situation to the cups of water from the food coloring investigation in the previous lesson.



Two samples of water, one hot and one cold.



Food coloring is added to both samples.



The food coloring spreads more quickly through the hot water than the cold water.

1. Open the Simulation.
2. Add two same-sized samples.
3. Make one sample hot and one sample cold.
4. Observe the differences in the two samples.

What do you notice about the movement of the molecules of the two samples?

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Explain what you discovered from the Simulation about why food coloring spreads faster in warmer water.

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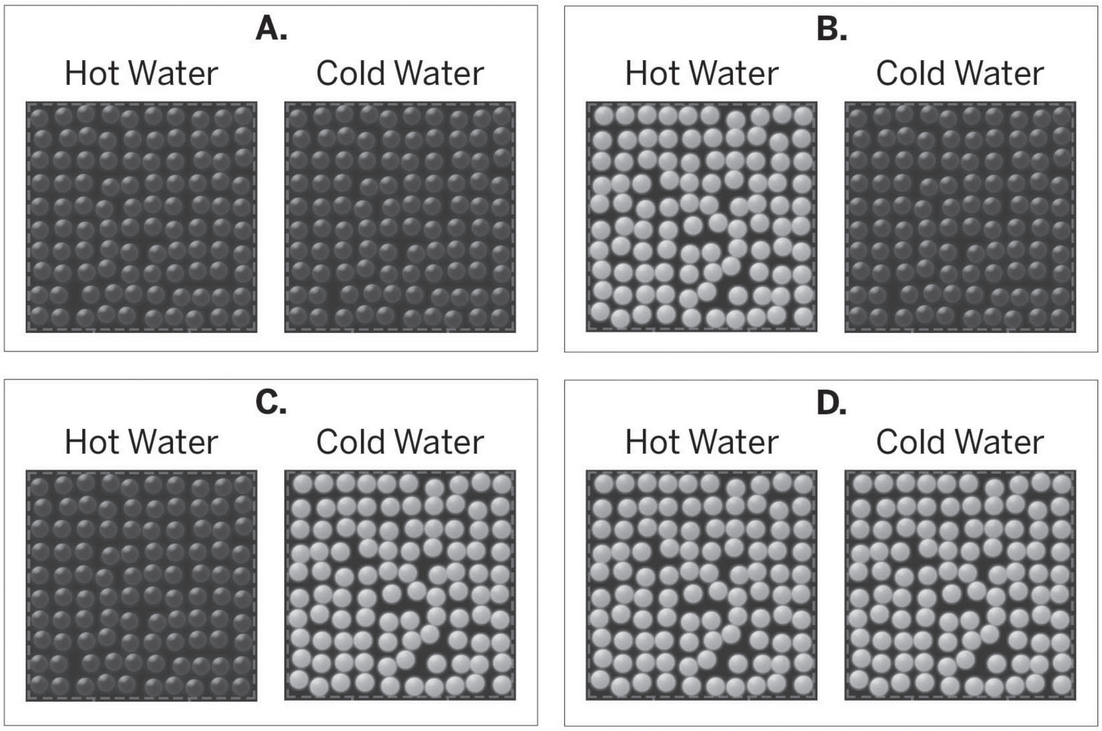
Name: ______________________________ Date: ____________________

Reflection

- Look at the key and four images below.
- Answer the reflection question, and explain your response.

Key: Molecule Speed 



Which image shows the difference between the speed of molecules in hot and cold water? (check one) (**Hint:** Refer to the key above the images.)

☐ A ☐ B ☐ C ☐ D

Explain your answer choice.

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Name: ______________________ Date: ______________

Homework: Reading "Absolute Zero"

Read "Absolute Zero" and annotate the article with your own ideas and questions. When you are finished, answer the questions below.

1. Which of the following would be true if something was at absolute zero? (check one)

   ☐ The molecules that make up a sample wouldn't be moving.

   ☐ The molecules that make up a sample would be moving very slowly.

   ☐ The molecules that make up a sample would be moving very fast.

2. If the molecules of a sample speed up, what else happens? (check one)

   ☐ The temperature of the sample decreases.

   ☐ The temperature of the sample increases.

   ☐ The temperature of the sample stays the same.

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ____________________

Lesson 1.4: Molecules and Temperature

Is there a limit to how hot or cold something can be? What does temperature really tell us? Today, you'll use what you've learned in this chapter to reflect on these questions, and you will learn how calculating an average can help you think about temperature. Then, you'll create a model for the principal that shows how the air inside Riverdale School is different when it is warmer instead of cooler.

Unit Question

- Why do things change temperature?

Chapter 1 Question

- What is happening when the air in the school gets warmer?

Key Concepts

- Things are made of molecules (or other types of atom groups).
- When a thing gets hotter, its molecules are moving faster.
- When a thing gets colder, its molecules are moving slower.
- Temperature is a measure of the average speed of the molecules of a thing.

Vocabulary

- average
- molecule
- temperature

Name: ______________________________ Date: ________________

Warm-Up

Revisiting "Absolute Zero"

Read the following quote from the article "Absolute Zero" and answer the questions below. If necessary, refer to the article.

> "This is because temperature is determined by average molecular movement, and there is a limit to how slowly something can move. After all, if something slows down completely, it just stops moving."

Is there a limit to how cold things can get? (check one)

☐ Yes, there is. ☐ No, there is not.

Explain your answer using evidence from the article.

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Redefining Temperature

What does the article "Absolute Zero" tell us about what temperature really means? After the class discussion, if your ideas have changed, revise your answer to the Warm-Up below.

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Name: ______________________________ Date: ________________

Calculating the Average Speed of Molecules

Below are two diagrams that show things made of molecules moving at different speeds. Calculate the average speed of the molecules in Diagram 1 and Diagram 2 by adding the numbers together and dividing by the number of molecules in the diagram. Be sure to show your work. When you are finished, answer the questions below.

Diagram 1

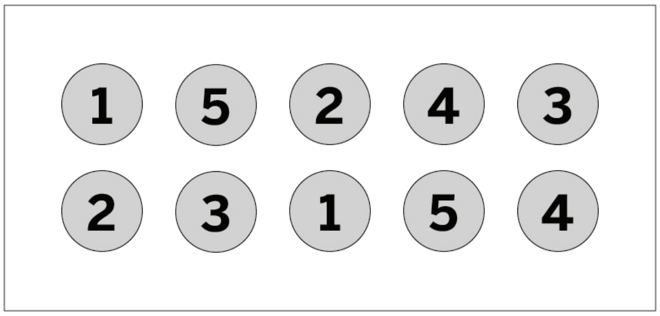
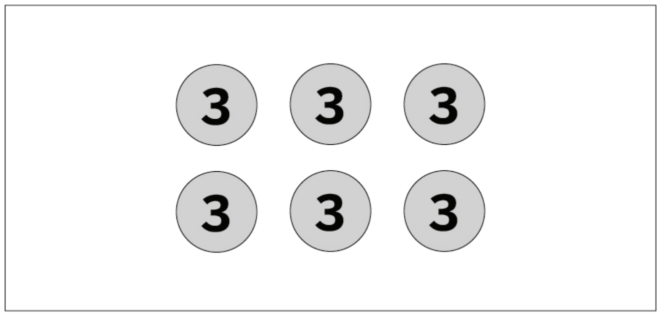


Diagram 2



The average speed of the molecules in Diagram 1 is: (circle one)

2 3 5 10 30

The average speed of the molecules in Diagram 2 is: (circle one)

2 3 5 10 30

What can you tell about the temperature of the things in these diagrams by calculating the average speed of the molecules? (check one)

- ☐ The thing in Diagram 1 has a higher temperature than the thing in Diagram 2.
- ☐ The thing in Diagram 2 has a higher temperature than the thing in Diagram 1.
- ☐ The things in both diagrams have the same temperature.

Name: ______________________ Date: ______________

Modeling Differences in Temperature

Use the Modeling Tool: Differences in Temperature sheet on the next page to help you show the Riverdale principal what happens when the air inside Riverdale School gets warmer.

Goal: Create a model that shows the difference between warmer and cooler air.

Do:

- In the "Colder Air" space, draw how the molecules in the air look when the air is colder.
- In the "Warmer Air" space, draw how the molecules in the air look when the air is warmer.
- When you have finished, write a short explanation of your model at the bottom of your sheet.

Tips:

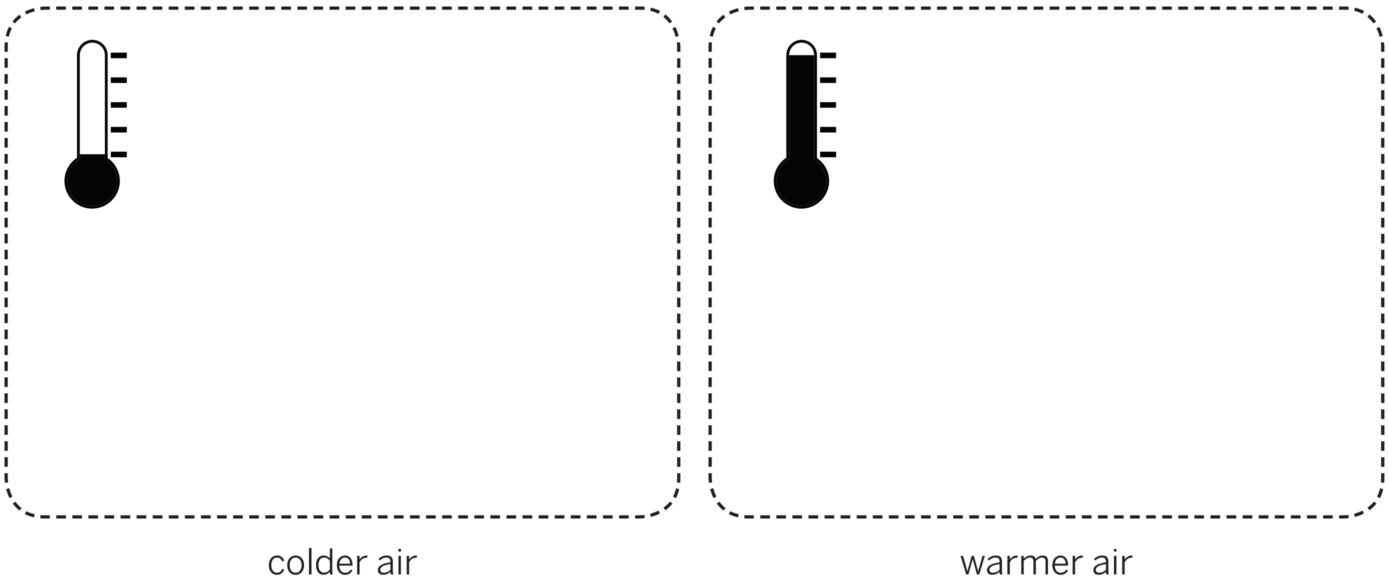
- Use the "Molecule Speed" key on the right side of the sheet to help you make your model.
- Be sure to show the difference between warmer and colder air in your model and include it in your explanation.

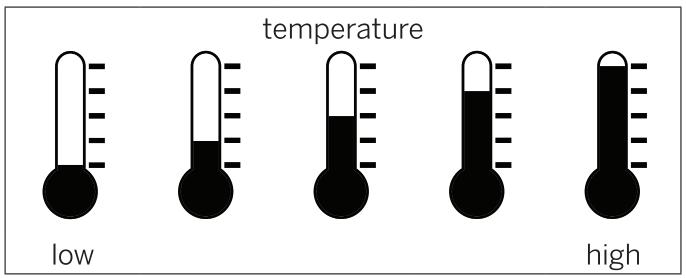
Name: ______________________ Date: ______________

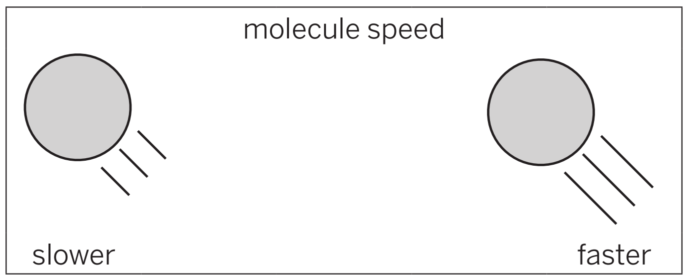
Modeling Differences in Temperature (continued)

Differences in Temperature Modeling Tool

Goal: Create a model that shows the difference between warmer and cooler air.





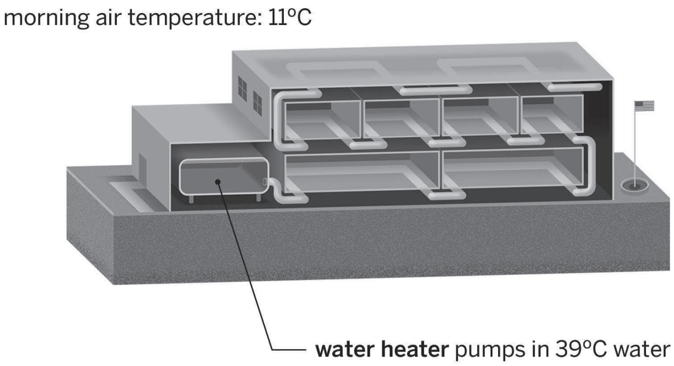


Name: ______________________________ Date: ________________

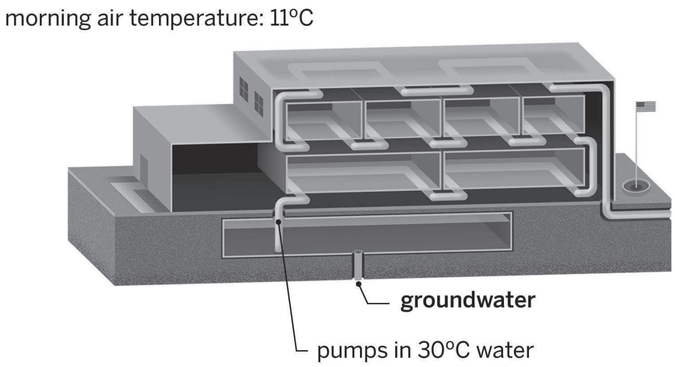
Considering the Heating Systems

Below are two diagrams showing the proposed heating systems being considered by the principal of Riverdale School. Based on what you know so far, answer the questions below.

Proposal #1:
Water Heater System



Proposal #2:
Groundwater System



Consider the molecules in the two proposed systems. How are they the same and how are they different?

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At this point, I think the **(water heater system / groundwater system)** will warm Riverdale School more. (circle one)

Name: ______________________________ Date: ________________

Homework: Revisiting the Anticipation Guide

Below are two statements from the Anticipation Guide that you completed on page 6. Look back at each statement and decide whether you agree or disagree with it at this point. Then try revising each statement to make it more complete or correct.

Temperature is a measure of how hot or cold something is. (check one)

☐ agree ☐ disagree

How could you revise this statement to be more complete or correct?

____

____

____

When something heats up, it moves faster, and when it cools down, it moves slower. (check one)

☐ agree ☐ disagree

How could you revise this statement to be more complete or correct?

____

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Name: ______________________________ Date: ________________

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions on this page and the next page.

Scientists investigate in order to figure things out. Are you getting closer to figuring out which heating system will warm the air inside Riverdale School more?

1. I understand the difference between the motion of the air molecules in the school and the air molecules in each heating system. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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2. I understand why the air in the school will change temperature when it comes into contact with water from a heating system. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

____

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3. I understand what factors determine how much the motion of the air molecules in the school will change. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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Name: ______________________________ Date: ________________

Homework: Check Your Understanding (continued)

4. What do you still wonder about which heating system will warm the air in the school more?

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Name: ______________________________ Date: ________________

Chapter 2: Temperature and Energy
Chapter Overview

Now that you know that molecules speed up when they increase in temperature, you know that the heating systems, if they work properly, should speed up the air molecules inside the school. But what causes molecules to speed up? In this chapter you will investigate why changes in temperature occur.

Name: ______________________________ Date: ______________

Lesson 2.1: Visualizing Motion Energy

Riverdale School needs your help to choose a heating system. Both systems use water to heat the air, but how can water even heat air? We already know that when things heat up, their molecules move faster, but why? In this lesson, you will begin investigating why molecules change speed so you can figure out what causes the air molecules inside the school to speed up. This will help you to figure out if and how the heating systems work.

Unit Question

- Why do things change temperature?

Chapter 2 Question

- What causes the air molecules inside the school to speed up?

Vocabulary

- average
- infer
- kinetic energy
- molecule
- temperature

Digital Tool

- *Thermal Energy* Simulation

Name: ______________________ Date: ______________

Warm-Up

Letter from a Concerned Parent

Dear Mr. Chang,

I am worried about your proposal to install a groundwater heating system in my daughter's school.

I don't think that water at a temperature of 30°C has enough energy to heat the school. If the school is too cold, the students won't be able to focus on learning.

Sincerely,

David Li

What do you think energy is?

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What do you think energy has to do with the heating systems?

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Name: ______________________________ Date: ______________

Visualizing Motion as Energy

Use the *Thermal Energy* Simulation to explore kinetic energy.

Part One

1. Open the Simulation.
2. Add one sample and turn on the View Kinetic Energy toggle.
3. Explore different ways to change the kinetic energy of your sample.

Based on your exploration in the Sim, what do you notice about kinetic energy?

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Part Two

Start over by resetting the Simulation.

1. Add two samples.
2. Do not turn on the View Kinetic Energy toggle yet.
3. Make one sample have faster molecules than the other sample. What do you predict about the molecules of the two samples? (circle one)

   I predict that the warmer sample with faster molecules will have **(more / less)** kinetic energy than the colder sample with slower molecules.
4. Turn on the View Kinetic Energy toggle to check your prediction. What did you observe about the molecules of the two samples? (circle one)

   I observed that the warmer sample with faster molecules will have **(more / less)** kinetic energy than the colder sample with slower molecules.

Name: ______________________________ Date: ________________

Word Relationships

Use the vocabulary words we have learned so far in this unit to describe what happens when something warms up.

1. With your group, think of something you have observed getting warmer. You will create sentences about this object.
2. Use at least two different Word Relationships Cards to create a sentence describing what happens when your object warms up.
   - In your group, take turns as both the speaker and the listener.
   - Your group may use the same word more than once. You do not need to use all the vocabulary words.
   - There are many different ways to explain what happens when something warms up, and you may need to create more than one sentence in order to express your ideas completely.

Word Bank

average	infer	kinetic energy	molecule

Name: ______________________________ Date: ________________

Lesson 2.2: "How Air Conditioners Make Cities Hotter"

Air conditioning keeps our schools, our cars, and our homes comfortable even as the temperature rises outside. But as the air inside cools and its molecules slow down, what happens to the kinetic energy those molecules had when the air was warmer? Today, you'll read "How Air Conditioners Make Cities Hotter," an article about how heating and cooling have more in common than you might think.

Unit Question

- Why do things change temperature?

Chapter 2 Question

- What causes the air molecules inside the school to speed up?

Key Concepts

- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.

Vocabulary

- average
- collision
- infer
- kinetic energy
- molecule
- system
- transfer

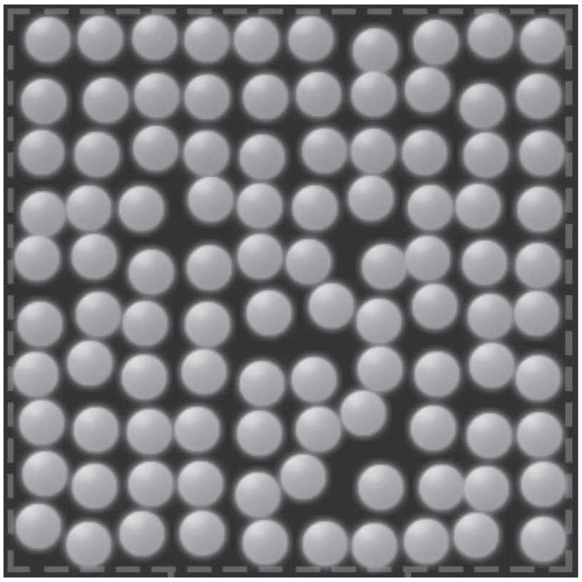
Name: ______________________ Date: ______________

Warm-Up

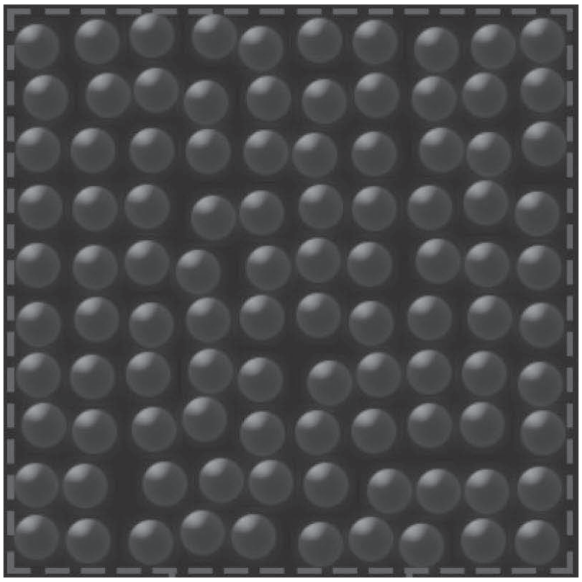
Relating Temperature, Speed, and Kinetic Energy

Below are diagrams representing the molecules of three pairs of samples. For each pair, label one sample as "hotter" and the other as "colder" based on your interpretation of the diagrams and your knowledge of how temperature, speed, and kinetic energy are related. If you need to, you can refer to the key concepts posted to the classroom wall. When you have finished labeling the images, answer the questions on the next page.

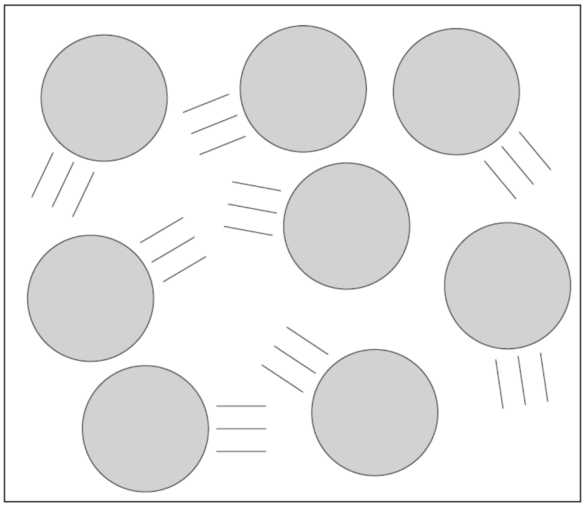
Sample A



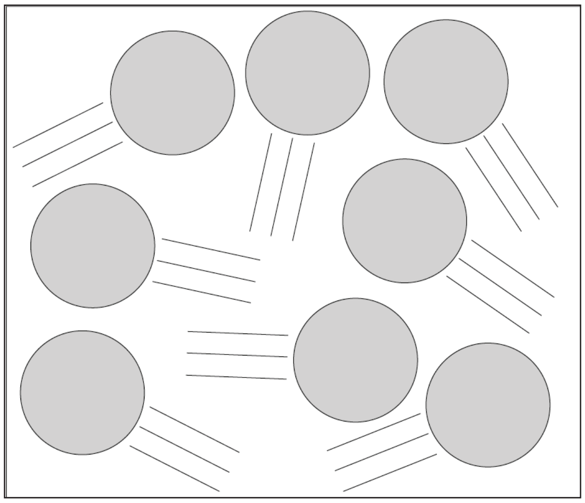
Sample B



Sample C



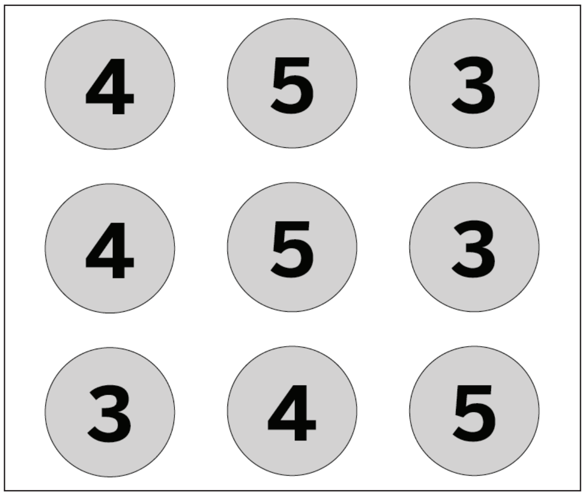
Sample D



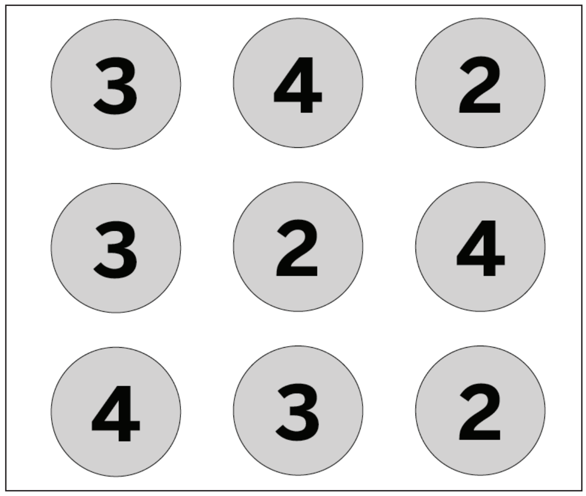
Name: ____________________ Date: ____________

Warm-Up (continued)

Sample E



Sample F



The average kinetic energy of the molecules that make up Sample E is: (circle one)

3 4 5 36

The average kinetic energy of the molecules that make up Sample F is: (circle one)

2 3 4 27

Name: ______________________________ Date: ______________

Reading "How Air Conditioners Make Cities Hotter"

1. Read and annotate the article "How Air Conditioners Make Cities Hotter."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement.

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost Never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ________________________________ Date: ____________________

Lesson 2.3: Analyzing Evidence and Evaluating Claims

You know that molecules can change speed, moving faster when things are warmer and slower when things are cooler. But why do these changes happen? Earlier in this chapter, you learned that a change in speed is also a change in kinetic energy. Today, you'll evaluate two claims about how energy causes molecules to change speed, using the Sim and revisiting "How Air Conditioners Make Cities Hotter" to gather evidence.

Unit Question

- Why do things change temperature?

Chapter 2 Question

- What causes the air molecules inside the school to speed up?

Key Concepts

- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.

Vocabulary

- average
- collision
- infer
- kinetic energy
- molecule
- system
- transfer

Digital Tool

- *Thermal Energy* Simulation

Name: ______________________________ Date: ________________

Warm-Up

Today you will investigate two claims about why molecules change speed.

- First, look at the claims below and check the one you think is more likely to be correct.
- Then, open the Sim and begin exploring. Gather and record evidence that will help you choose between the claims. You will have more time to record evidence later in this lesson.

Investigation Question: *Why do molecules change speed?* (check one)

☐ **Claim 1:** Molecules speed up when energy is created and slow down when energy is destroyed.

☐ **Claim 2:** Molecules speed up when they get energy from other molecules and slow down when they give energy to other molecules.

Once you have chosen a claim, launch the *Thermal Energy* Simulation and begin gathering evidence in the Sim.

What evidence did you gather about the claims?

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Name: ______________________________ Date: ________________

Simulating Temperature Change

With a partner, continue to use the Sim to gather and record evidence about the claims.

Investigation Question: *Why do molecules change speed?*

Claim 1: Molecules speed up when energy is created and slow down when energy is destroyed.

Claim 2: Molecules speed up when they get energy from other molecules and slow down when they give energy to other molecules.

1. Launch the Sim.
2. Add two samples of the same size.
3. In Run, press the View Kinetic Energy toggle and the View Energy Transfer toggle.
4. Press the + or - buttons to add or remove energy so that one sample is warmer and the other sample is colder.
5. Drag the two samples together and observe what happens.
6. Open Analyze. Replay the Sim and observe what happens on the graph after the two samples are dragged together.
7. Build on any evidence you observed during the Warm-Up and complete the sentence at the bottom of the page. Be sure to mention evidence from both Run and Analyze.

What evidence did you gather about the claims?

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____

The evidence I gathered supports ________________. (check one)

☐ Claim 1

☐ Claim 2

☐ Claims 1 and 2

Name: ____________________ Date: ____________

Revisiting “How Air Conditioners Make Cities Hotter”

Continue to gather evidence about the two claims by rereading a portion of the article “How Air Conditioners Make Cities Hotter.” Start at the fifth paragraph (which begins, “This kind of energy transfer doesn’t just apply to hot buildings: it also applies to hot foreheads!”), and stop after the seventh paragraph (which ends, “When that happens, it’s time to get a new, cool washcloth so that this energy transfer can keep going and you can keep getting relief!”). Use the evidence you gathered from the text to complete the sentence below.

Investigation Question: *Why do molecules change speed?*

Claim 1: Molecules speed up when energy is created and slow down when energy is destroyed.

Claim 2: Molecules speed up when they get energy from other molecules and slow down when they give energy to other molecules.

What evidence did you gather about the claims?

____

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____

The evidence I gathered supports ____________. (check one)

☐ Claim 1

☐ Claim 2

☐ Claims 1 and 2

Name: ______________________________ Date: ________________

Reflection

Choosing a Claim

Think back on the evidence that you collected from the Sim and the article. Choose the claim that you think is best supported by this evidence.

Investigation Question: *Why do molecules change speed?* (check one)

☐ **Claim 1:** Molecules speed up when energy is created and slow down when energy is destroyed.

☐ **Claim 2:** Molecules speed up when they get energy from other molecules and slow down when they give energy to other molecules.

Name: ______________________________ Date: ____________________

Homework

Making a Convincing Argument

Kalani and Lael are students who have been asked to explain why freeze ray guns can't shoot "cold" at people. Read and compare their arguments. Then, answer the questions below.

Kalani's Argument

A freeze ray cannot shoot "cold" because cold can't be transferred from one thing to another. Only energy can transfer.

Lael's Argument

A freeze ray cannot shoot "cold" because cold is not an object, it is a description of an object whose molecules have a small amount of kinetic energy.

In order to make something colder, kinetic energy has to be transferred out of it. Energy always transfers from the warmer thing to the colder thing, so you would have to put an even colder thing next to the person you were shooting so the kinetic energy would transfer out.

Which argument is more convincing? (circle one)

Kalani's argument

Lael's argument

What makes one argument more convincing than the other?

____

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Name: ______________________________ Date: ____________________

Lesson 2.4: Investigating Energy Transfer

You know that energy transfers from warmer things to colder things, but does energy transfer ever stop? In this lesson, you will use the Sim to collect data about energy transfer. Then you will work with a group to create a physical model of how and why energy transfers and when and why it stops.

Unit Question

- Why do things change temperature?

Chapter 2 Question

- What causes the air molecules inside the school to speed up?

Key Concepts

- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.
- When two things are in contact, their molecules collide, and kinetic energy transfers from the faster-moving molecules to the slower-moving molecules.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of a system as it decreases in another part of the system.

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- transfer

Digital Tool

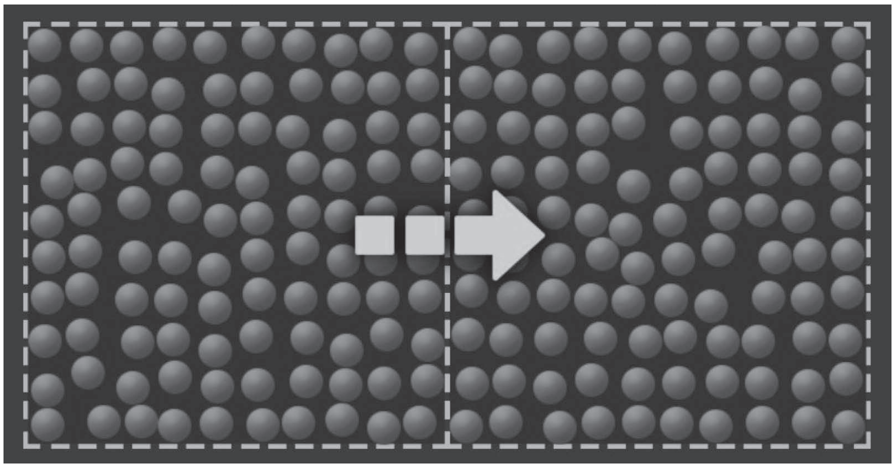
- *Thermal Energy* Simulation

Name: ______________________________ Date: ________________

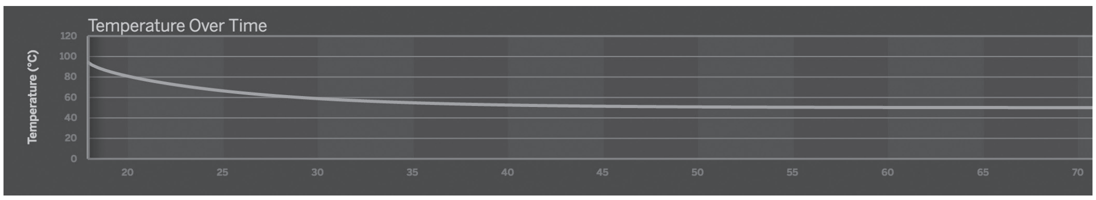
Warm-Up

Sample A and Sample B came into contact as shown below. The graph from the *Thermal Energy* Simulation shows information about how Sample A changed over time.

Sample A **Sample B**



Temperature Graph for Sample A



What does the graph tell you about the temperature of Sample A over time?

____

____

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____

What can you infer about what a temperature graph of Sample B would look like?

____

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Name: ______________________________ Date: ____________________

Investigating Energy Transfer

Use the Sim to examine how the temperature and energy of Samples A and B change after the samples come into contact.

1. Open the Simulation.
2. Add two samples of equal size.
3. Turn on the View Kinetic Energy toggle.
4. Make Sample A much hotter than Sample B. Record the starting temperatures of both samples in the table below.
5. Turn on the View Energy Transfer toggle.
6. Push the samples together and wait until the energy stops transferring. Record the final temperatures of both samples in the table below.

	Sample A	**Sample B**
Starting temperature (°C)		
Final temperature (°C)		

Before coming into contact, the molecules of Sample A had ____________________ the molecules of Sample B. (circle one)

more kinetic energy than **less kinetic energy than** **the same kinetic energy as**

Once the energy stopped transferring, the molecules of Sample A had ____________________ the molecules of Sample B. (circle one)

more kinetic energy than **less kinetic energy than** **the same kinetic energy as**

Before the samples came into contact, the temperature of Sample A was ____________________ the temperature Sample B. (circle one)

higher than **lower than** **the same as**

Once the energy stopped transferring, the temperature of Sample A was ____________________ the temperature Sample B. (circle one)

higher than **lower than** **the same as**

Name: ____ Date: ____________________

Investigating Energy Transfer (continued)

1. Switch to Analyze and scroll back to the beginning of the run.
2. Focus on the Thermal Energy graph.
3. Record the total energy of the samples after you made one hot and one cold.
4. Scroll forward and record the total thermal energy after the run ends.

	Sample A	**Sample B**
Starting thermal energy (kJ)		
Final thermal energy (kJ)		

The thermal energy of Sample A _____________. (check one)

☐ increased

☐ decreased

☐ stayed the same

The thermal energy of Sample B _____________. (check one)

☐ increased

☐ decreased

☐ stayed the same

Why did the transfer of energy between the two samples stop?

____

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Name: ______________________________ Date: ________________

Using the Energy Cube Model

Demonstrating Energy Transfer

Goals:

- Demonstrate what happens when a warmer object comes into contact with a colder object.
- Show as many key concepts as you can in your model.

Reminders:

- Each person represents a molecule.
- Each group of four people represents one object.
- Cubes represent kinetic energy.
- All 32 cubes must be used in the model.

1. Decide which group of four will be Object 1 (warmer) and which will be Object 2 (colder).
2. Using your graphic organizers, decide how many of the 32 energy cubes each group (object) and each person (molecule) should take to accurately represent the fact that they are warmer or colder. Put the cubes on the molecules to show what you decide.
3. Discuss how many energy cubes should transfer from one object to the other when the objects come into contact, and how you know when to stop transferring energy cubes. Plan how you will show what happens when the objects come into contact.
4. Get up, distribute the cubes as you planned, and act out your physical model!

Name: ______________________ Date: ______________

Reflecting on Stability and Change

Reflecting on Equilibrium

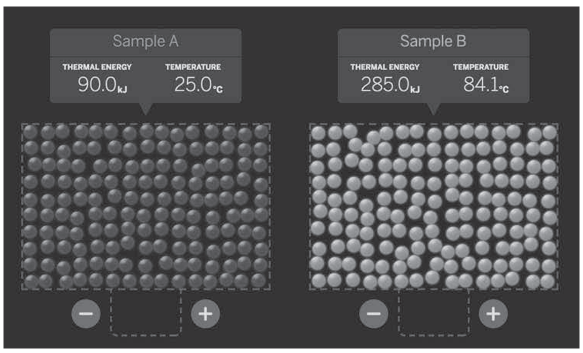
The diagrams below show the kinetic energy of different samples that are not yet in contact, but that may be in contact in the future. With your partner, predict what will happen in each system should their samples come in contact.

Select the systems below in which the samples will change if the samples come into contact. (Check all that apply.)

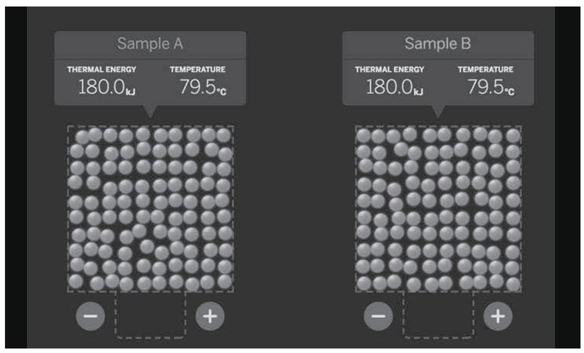
- ☐ The samples will not change in any of these systems.
- ☐ System 1
- ☐ System 2
- ☐ System 3
- ☐ System 4

Discuss with your partner why you chose the answer(s) you did. For samples that will change, what will happen over time?

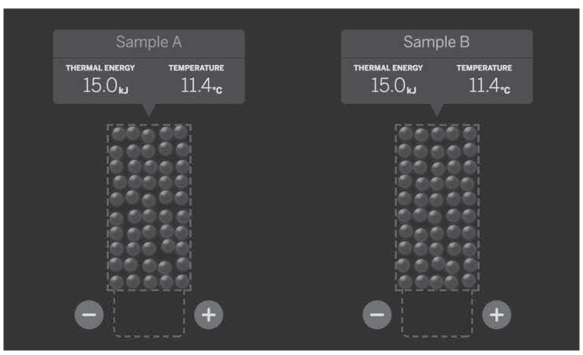
System 1



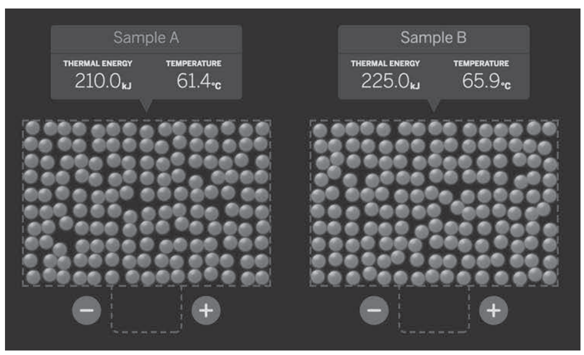
System 2



System 3



System 4



Name: ______________________________ Date: ________________

Homework: Reading "Molecule Collisions and Newton's Cradle"

As you read the article "Molecule Collisions and Newton's Cradle," annotate it with your own ideas and questions. When you have finished, answer the question below.

When a moving object collides with an object that isn't moving, what happens to the kinetic energy of each object?

____

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Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ____________________ Date: ____________

Lesson 2.5: Explaining Changes in Temperature

Now that you understand why things change temperature, it's time to revisit the letter that David Li wrote to the principal. Was Mr. Li right to be skeptical about the groundwater system? How would either of the systems change the air temperature in the school? Today, you'll have a chance to use what you've learned to make a model for the principal.

Unit Question

- Why do things change temperature?

Chapter 2 Question

- What causes the air molecules inside the school to speed up?

Key Concepts

- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.
- When two things are in contact, their molecules collide, and kinetic energy transfers from the faster-moving molecules to the slower-moving molecules.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of the system as it decreases in another part of the system.

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- transfer

Name: ______________________________ Date: ________________

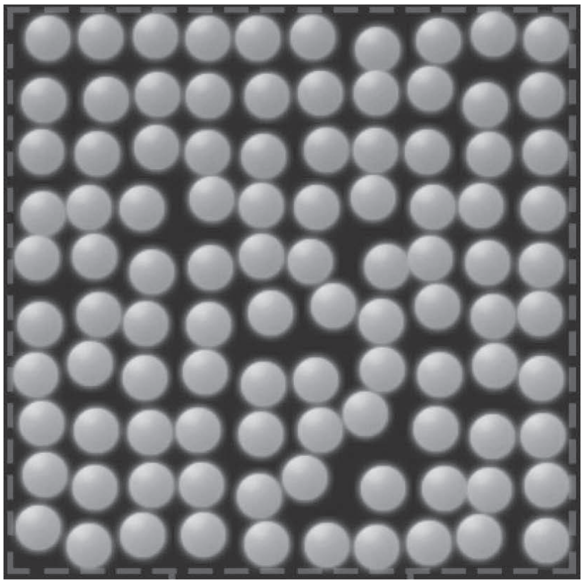
Warm-Up

Thinking About Equilibrium

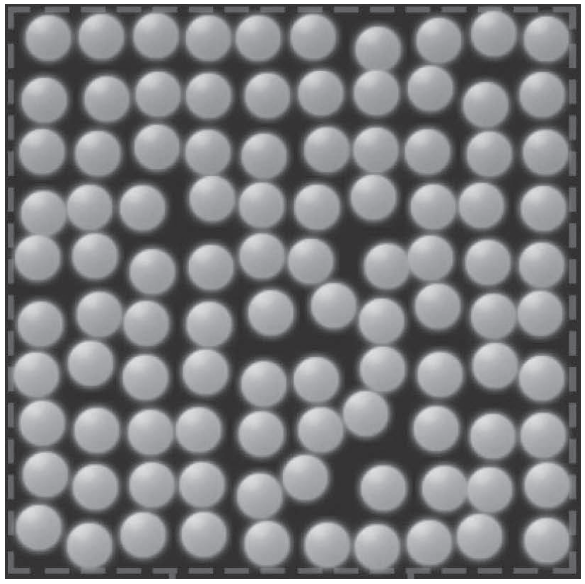
Below are visual representations of three pairs of samples: A and B, C and D, E and F. The samples in each pair are in contact. Based on your interpretation of the diagrams and your knowledge of kinetic energy transfers, label each pair of samples as "at equilibrium" or "not at equilibrium."

- Remember that the definition of *equilibrium* is "a balanced state at which a system is stable, such as when two or more samples are at the same temperature." Refer to the key concepts posted to the classroom wall if you need help.
- When you have finished labeling the images, complete the sentences on the next page.

Sample A



Sample B



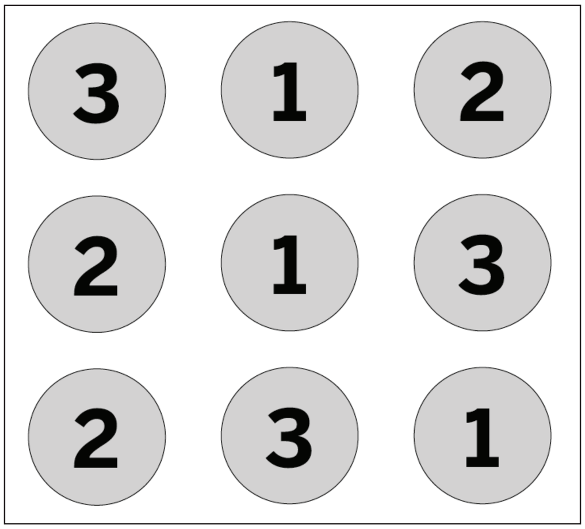
Sample C

Sample D

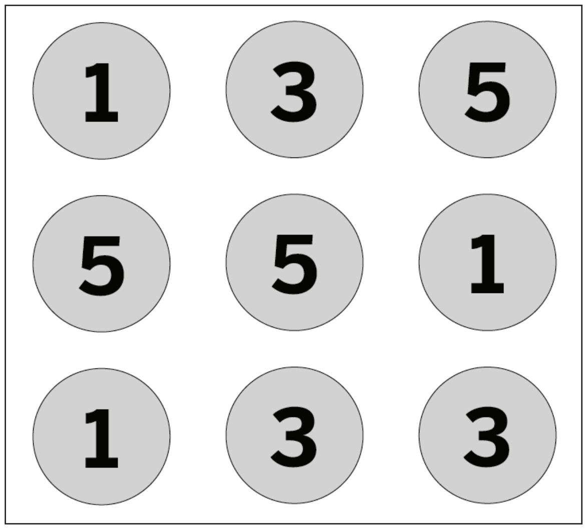
Name: ______________________________ Date: ________________

Warm-Up (continued)

Sample E



Sample F



The average kinetic energy of the molecules that make up Sample E is: (circle one)

1 2 3 18

The average kinetic energy of the molecules that make up Sample F is: (circle one)

1 3 5 27

Name: ______________________________ Date: ________________

Word Relationships Routine

With your group, use the vocabulary words we have learned so far in this unit to answer the Investigation Question: *Why does the transfer of energy between two things stop?*

- Use at least two words from the Word Relationships Cards in each sentence. Take turns as both the speaker and the listener.
- You and your partner may use the same word more than once. Try to use all the vocabulary words.
- There are many different sentences that could help to answer the Investigation Question. You and your partner will need to create multiple sentences in order to answer the question completely.

Word Bank

average	equilibrium	infer	kinetic energy	collision
molecule	system	transfer	stability	change

Name: ______________________________ Date: ________________

Modeling Temperature Change

Part 1: Temperature Change Model

Use the Modeling Tool: Temperature Change student sheet on the next page to help you respond to David Li's claim that the water in the groundwater system is not warm enough to heat the air inside the school.

Goal: Create a model that shows the difference between warmer and cooler air.

Do:

- On the left, examine the mostly-completed Morning model, which represents the air inside the school and the groundwater below the school immediately after coming into contact (right after the heaters were turned on).
- In the empty square in the Morning model, draw an energy arrow that shows the direction that energy transfer is occurring in this system
- On the right, complete the Afternoon model, filling in the molecules, molecule speeds, temperatures, and energy transfer arrows, to show what the system would look like after the air inside the school and the groundwater below the school have been in contact for several hours.

Tips:

- Use the key on the right side of the sheet to help you make your model.
- Don't forget the key concepts while you make your model.

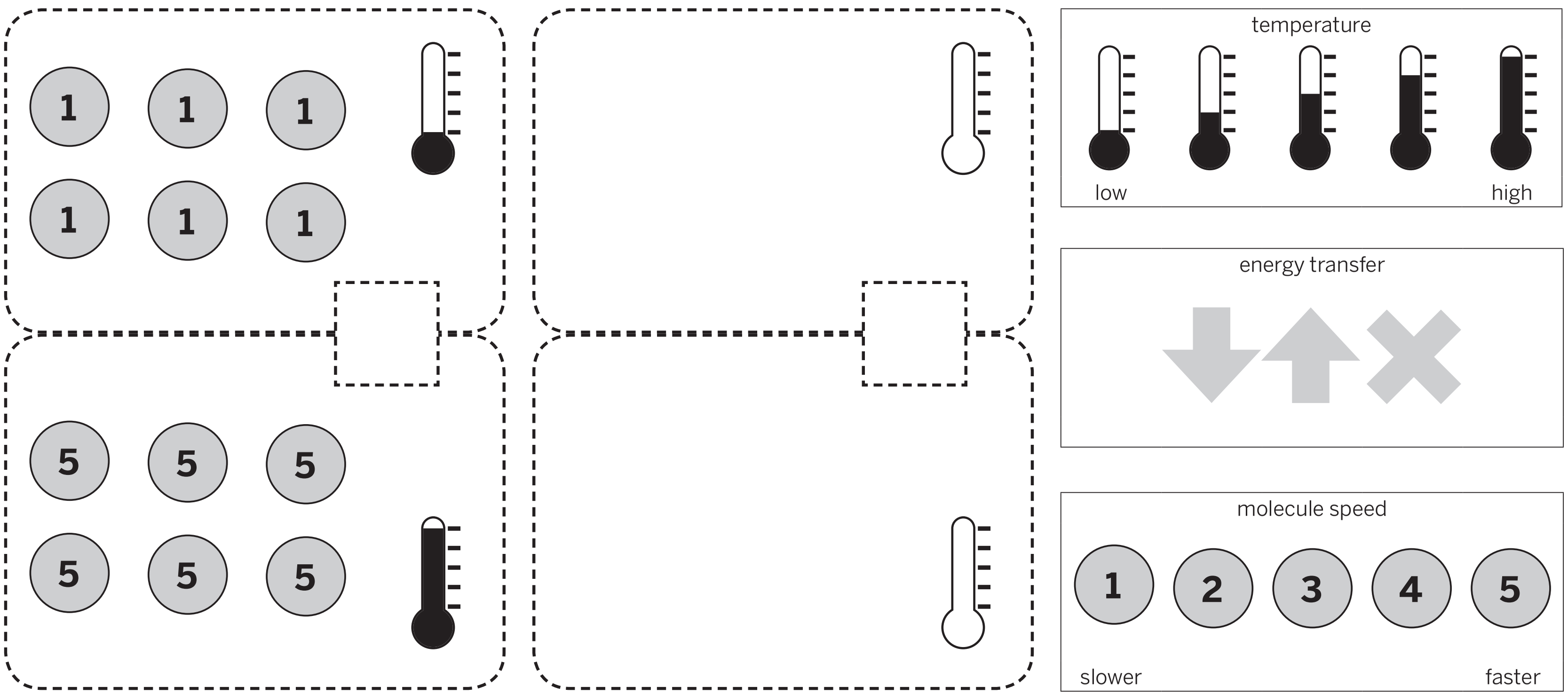
Name: ______________________ Date: ______________

Modeling Temperature Change (continued)

Temperature Change Modeling Tool

Goal: Create a model that shows how the warm water below the school will warm the air inside the school.

Morning air inside school | **Afternoon** air inside school



warm water below school | warm water below school

Name: ______________________________ Date: ________________

Modeling Temperature Change (continued)

Part 2: Stability and Change at Riverdale School

Answer the questions below, using your model and the new key concept: *The molecules of a system will transfer energy until the system reaches a stable state known as equilibrium, in which all of the molecules are moving at about the same speed.*

Respond to David Li's letter. Explain how the groundwater system could heat the air in the school.

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Explain what would happen to the air temperature at Riverdale School if the groundwater system were used. Use the terms **stability** and **change** in your explanation.

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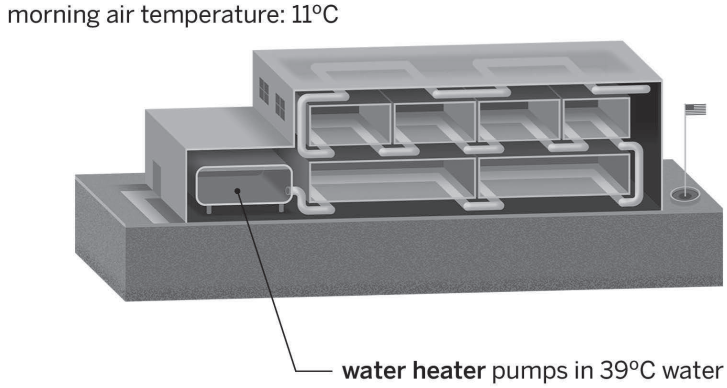
Name: ______________________________ Date: ________________

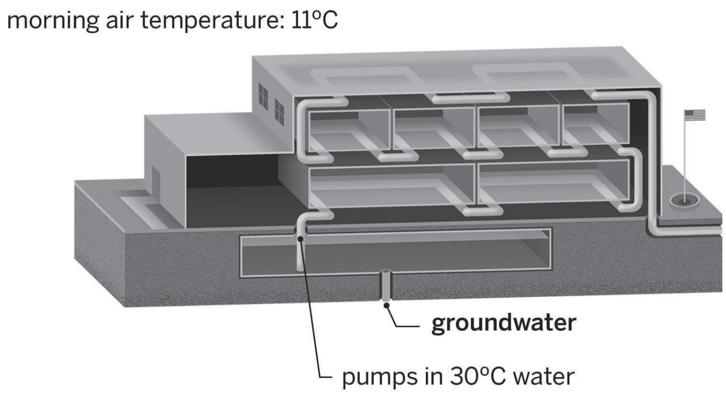
Comparing the Heating Systems

Here are the two proposed heating systems that the principal is considering. Based on what you've learned so far, discuss with a partner which of the two systems you think will do a better job of warming Riverdale School, and why you think so. Then, answer the question below.

Proposal #1:
Water Heater System



Proposal #2:
Groundwater System



At this point, I think the ________________ will warm Riverdale School more. (circle one)

water heater system **groundwater system**

Name: ______________________________ Date: ____________________

Homework: Revisiting the Anticipation Guide

Below is a statement from the Anticipation Guide that you completed at the beginning of this unit on page 6. Look back at the statement and decide whether you agree or disagree with it at this point. Then, try revising the statement to make it more complete or correct.

When something heats up, new energy is created, and when something cools down, energy is destroyed. (check one)

☐ agree ☐ disagree

How could you revise this statement to be more complete or correct?

____

____

____

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____

____

Name: ______________________________ Date: ________________

Lesson 2.7: Revisiting Energy and Molecules

Today, you will be using the Sim to review some of the big ideas that have been introduced in the first two chapters of this unit. Then, you'll get ready to play the Energy 3-in-a-Row game with a partner. In order to win, you'll need to use what you've learned so far about temperature, kinetic energy, and energy transfer. Are you ready? Let's play!

Unit Question

- Why do things change temperature?

Chapter 2 Question

- What causes the air molecules inside the school to speed up?

Key Concepts

- Things are made of molecules (or other types of atom groups).
- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.
- When two things are in contact, their molecules collide, and kinetic energy transfers from the faster-moving molecules to the slower-moving molecules.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of the system as it decreases in another part of the system.
- The molecules of a system will transfer energy until the system reaches a stable state known as equilibrium, in which all of the molecules are moving at about the same speed.

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- transfer

Digital Tool

- *Thermal Energy* Simulation

Name: ______________________________ Date: ________________

Purple Group: Warm-Up

Reviewing Key Ideas in the Sim

Use the Sim to observe a hot and cold sample, and answer the questions below.

1. Launch the *Thermal Energy* Sim.
2. Add two same-sized samples.
3. Use the +/- buttons to make one sample as hot as possible and the other sample as cold as possible.
4. Turn on the View Kinetic Energy toggle.
5. Observe the samples and write whether you **agree** or **disagree** next to the statements below.

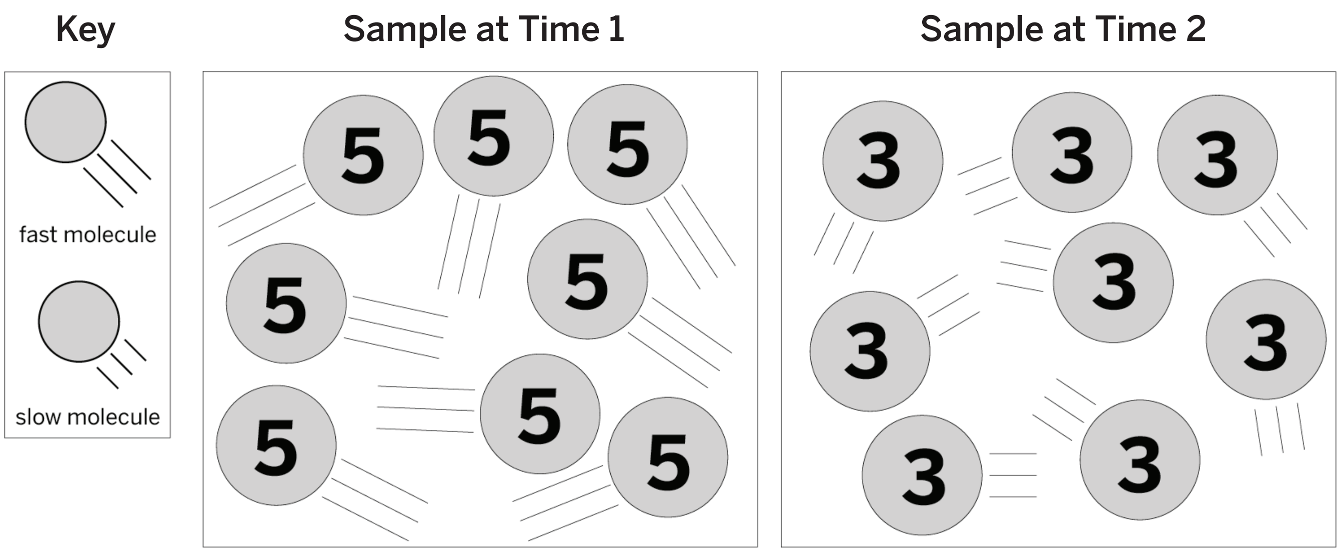
__________ Both samples are made of molecules.

__________ The molecules of both samples are moving.

__________ The molecules of both samples are moving at the same speed.

__________ The molecules of both samples have the same average kinetic energy.

The molecular images below show a sample that changed from Time 1 to Time 2. Based on what you observed in the Sim, use the diagrams to answer the questions below.



Between Time 1 and Time 2, the sample ______________. (circle one)

got hotter **got colder** **stayed the same temperature**

Name: ______________________________ Date: ________________

Purple Group: Warm-Up (continued)

Explain your answer choice using evidence from the molecular diagram.

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Name: ______________________________ Date: ________________

Green Group: Warm-Up

Reviewing Key Ideas in the Sim

Use the Sim to observe a hot and cold sample and review energy transfer.

1. Launch the *Thermal Energy* Simulation.
2. Add two same-sized samples.
3. Use the +/- buttons to make one sample as hot as possible and the other sample as cold as possible.
4. Turn on the View Kinetic Energy toggle.
5. Observe the samples and answer the questions below.

The molecules of the hotter sample have ________________ the molecules of the colder sample. (check one)

- ☐ a higher average kinetic energy than
- ☐ a lower average kinetic energy than
- ☐ the same average kinetic energy as

If the two samples are placed into contact, what do you predict will happen and why?

____

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Name: ______________________________ Date: ______________

Green Group: Warm-Up (continued)

1. Reopen the Sim.
2. Add two same-sized samples.
3. Use the +/- buttons to make one sample as hot as possible and the other sample as cold as possible.
4. Turn on the View Energy Transfer toggle.
5. Select the samples and drag them into contact.
6. Observe the samples and answer the questions below.

After the two samples were moved into contact, the hotter sample ___________. (check one)

☐ gained kinetic energy

☐ lost kinetic energy

☐ did not change

After the two samples were moved into contact, the colder sample ___________. (check one)

☐ gained kinetic energy

☐ lost kinetic energy

☐ did not change

How is energy transferred between molecules?

____

____

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Name: ______________________________ Date: ________________

Blue Group: Warm-Up

Examining a Changing Sample

Use the Sim to complete the mission described below.

Mission: Observe some of the molecules of a sample in the Sim moving faster or slower than other molecules of that same sample.

1. Launch the *Thermal Energy* Simulation.
2. Use the features of the Sim to to show the molecules described in the Mission.
3. Once you have made the observation described in the Mission, answer the following questions:

How did you set up the Sim in order to make the observation described in the Mission?

____

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____

____

Why do you think some of the molecules are moving faster or slower than others?

____

____

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____

Name: ______________________ Date: ______________

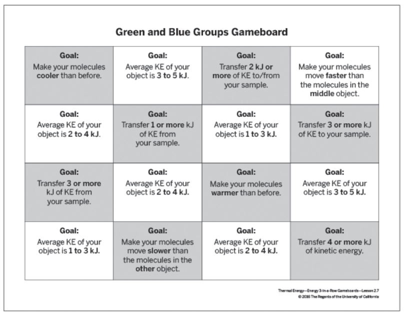
Blue Group: Warm-Up (continued)

Will the molecules of the sample continue to move at different speeds?

Name: ____________________________________ Date: ____________________

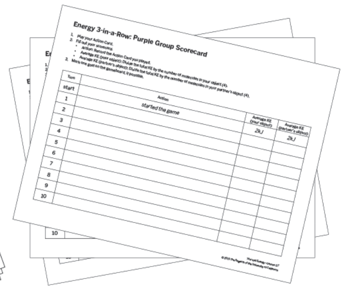
Getting Ready to Play Energy 3-in-a-Row

Today, you are going to play a game called Energy 3-in-a-Row with a partner. You will need the materials shown below.

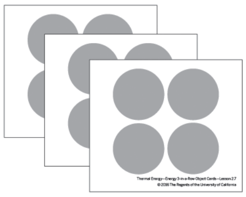


1 gameboard

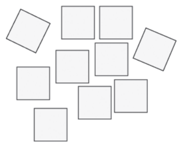
1 deck of Action Cards



3 scorecards



2 object cards (Purple)
3 object cards
(Green and Blue)



50 energy cubes

Goal: Be the first player to transfer different amounts of energy and change the kinetic energy of your object in different ways in order to mark three boxes in a row on the game board.

Setup:

- Each player gets one Object Card and places it face up on the table. In the Green and Blue games, the last Object Card is the "middle" object, and will be placed in between the two players.
- At the beginning of the game, place energy cubes on each Object Card so that each object has a **total** kinetic energy of 8kJ and an **average** kinetic energy per molecule of 2kJ.
- Shuffle the Action Cards and deal three to each player. Place the rest face down in a stack on the table.
- Decide which player will go first.

Playing the Game:

- There are different versions of the game for the Purple, Green, and Blue Groups. Make sure to read and follow the rules for your group!
- When you finish your game, you can move on to the next version of the game.

Name: ______________________________ Date: ____________________

Sharing Experiences

Talking About Energy 3-in-a-Row

Take a moment to think about your experience of playing Energy 3-in-a-Row. Then, discuss the following questions with your partner.

- Did you learn anything new by playing Energy 3-in-a-Row? If so, what?
- Did playing Energy 3-in-a-Row help you review any of the ideas from this unit? If so, which ones?

Name: ______________________________ Date: ________________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out which heating system will warm the air inside Riverdale School more?

1. I understand the difference between the motion of the air molecules in the school and the air molecules in each heating system. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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2. I understand why the air in the school will change temperature when it comes into contact with water from a heating system. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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3. I understand what factors determine how much the motion of the air molecules in the school will change. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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4. What do you still wonder about which heating system will warm the air in the school more?

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Name: ______________________________ Date: ____________________

Chapter 3: Changes in Temperature
Chapter Overview

You have discovered that both heating systems should work to increase the air temperature of the school. But which system will warm the school more? In this chapter you'll investigate factors that affect how much energy transfers and how much temperature changes. By the end of the chapter, you'll be able to choose the best heating system.

Name: ________________________________ Date: ____________________

Lesson 3.1: "Thermal Energy Is NOT Temperature"

Welcome back, student thermal scientists! Now that you know that the water used in the water heater system and the water used in the groundwater system are both warm enough to transfer kinetic energy to the air inside the school, how will you help the principal choose between the two? You know that the water used in the water heater system is warmer, but the groundwater system uses more water. Does that matter? Today, you'll read an article that looks closely at this very topic.

Unit Question

- Why do things change temperature?

Chapter 3 Question

- Which heating system will warm the air in the school more?

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- thermal energy
- transfer

Name: ______________________ Date: ______________

Warm-Up

Comparing an Average to a Total

On the left is an image of a small cup of tea. The water inside the teacup is very hot, about 80°C. On the right is an image of a large bathtub. The water inside the bathtub is warm, about 40°C.

A small cup of very hot water (80°C).

A large bathtub of warm water (40°C).

Which do you think has the greater *average* kinetic energy? (check one)

- ☐ the molecules of the water in the teacup
- ☐ the molecules of the water in the bathtub
- ☐ not sure

Which do you think has the greater *total* kinetic energy? (check one)

- ☐ the molecules of the water in the teacup
- ☐ the molecules of the water in the bathtub
- ☐ not sure

Name: ____________________ Date: ____________

Reading "Thermal Energy Is NOT Temperature"

1. Read and annotate the article "Thermal Energy Is NOT Temperature."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement.

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost Never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ________________

Homework: Sim Mission

Use the Sim to complete the mission below.

Mission: Observe the Sim showing a cooler sample that has more total kinetic energy (thermal energy) than a warmer sample.

1. Open the Simulation.
2. Use the features of the Sim to set up the samples as mentioned above and then observe the Sim.
3. Once you have observed the samples as described in the Mission, fill out the data table below. Then, answer the questions below.

	Colder sample	**Warmer sample**
Sample size		
Temperature (°C)		
Total kinetic energy (thermal energy) (kJ)		

How did you set up the Sim in order to make the observation described in the mission?

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Could you change your samples so that they both have the same amount of total kinetic energy (thermal energy)? How?

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Name: ________________________________ Date: ____________________

Lesson 3.2: Thermal Energy and Temperature Change

It is almost time for you to recommend a heating system to the principal! Before you choose, you need to dig a little deeper into the differences between the two systems. Today, you'll do so by beginning to investigate how differences in the total kinetic energy (thermal energy) of things can impact how much they will change temperature.

Unit Question

- Why do things change temperature?

Chapter 3 Question

- Which heating system will warm the air in the school more?

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- thermal energy
- transfer

Name: ______________________ Date: ______________

Warm-Up

Revisiting the Teacup and the Bathtub

In the last lesson, you compared a small teacup full of very hot water (80°C) to a large bathtub full of warm water (40°C). Below are two diagrams that use circles to represent molecules and numbers to represent how much kinetic energy each molecule has. Diagram 1 represents the bathtub full of warm water, and Diagram 2 represents the teacup full of hot water. Examine the diagrams and use them to answer the questions below. (**Remember:** In order to find the total kinetic energy of a thing, you need to add up the kinetic energy of all of its molecules.)

Diagram 1: Bathtub

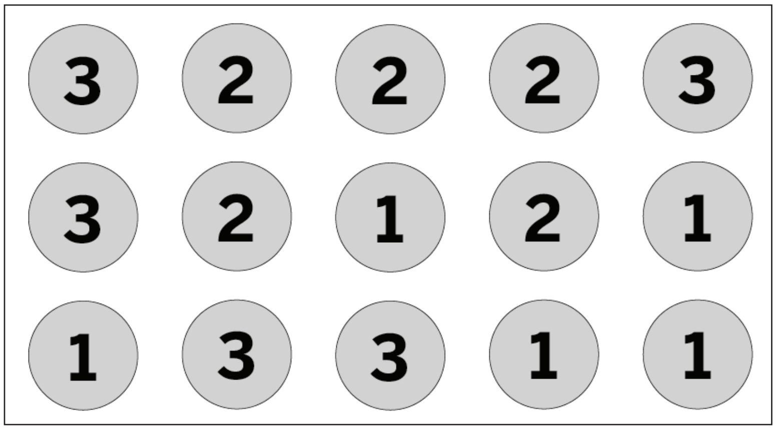
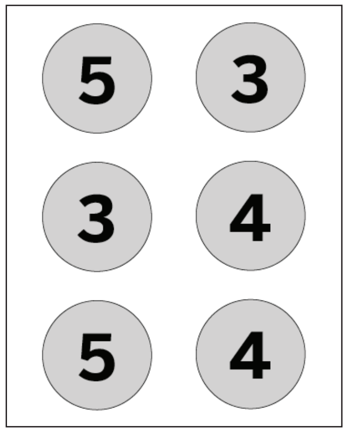


Diagram 2: Teacup



What is the total kinetic energy of the molecules in Diagram 1? ____________

What is the average kinetic energy of the molecules in Diagram 1? ____________

What is the total kinetic energy of the molecules in Diagram 2? ____________

What is the average kinetic energy of the molecules in Diagram 2? ____________

Complete these sentences.

The water in the teacup has **(higher / lower / the same)** average kinetic energy compared with the water in the bathtub. However, the water in the bathtub has **(greater / lower / the same amount of)** total kinetic energy because it has **(more molecules / fewer molecules / molecules with more energy / molecules with less energy)**.

Name: ______________________________ Date: ________________

Rereading "Thermal Energy Is NOT Temperature"

Reread the third paragraph of "Thermal Energy Is NOT Temperature" (which begins, "Since the two containers of soup began at the same temperature, the molecules in the bowl of soup and the mug of soup started off with the same average kinetic energy"). Think about the Investigation Question as you read. Be sure to review any diagrams you find in the text as these may also be used as evidence. Then, use the evidence you gathered from the text and the diagrams to answer the Investigation Question.

What determines how much total kinetic energy something has?

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Name: ______________________ Date: ______________

Revisiting the Energy Cube Model

Part 1: Modeling Objects of Different Sizes

Goal: Demonstrate the difference between average kinetic energy, total kinetic energy, and temperature.

Reminders:

- Object A has 6 molecules and Object B has 2 molecules.
- Each cube represents 1 kJ of kinetic energy.

Reviewing the difference between average kinetic energy, total kinetic energy, and temperature.

1. For each trial, set up your molecules with the average kinetic energy indicated in the table below. Be sure to use all 32 of your cubes.
2. Fill in the total thermal energy for both objects.
3. In the last column, select the statement that is true.
4. Repeat steps 1–2 for the next trials.

Trial	Object	**Average KE** (temperature)	**Total KE** (thermal energy)	**What is the state of the system?** (choose one option from below)
1	Object A larger: 6 molecules	4kJ		The system is at equilibrium because the objects are the same temperature. The system is not at equilibrium because Object A is colder than Object B. The system is not at equilibrium because Object B is colder than Object A.
	Object B smaller: 2 molecules	4kJ		
2	Object A larger: 6 molecules	3kJ		The system is at equilibrium because the objects are the same temperature. The system is not at equilibrium because Object A is colder than Object B. The system is not at equilibrium because Object B is colder than Object A.
	Object B smaller: 2 molecules	7kJ		
3	Object A larger: 6 molecules	5kJ		The system is at equilibrium because the objects are the same temperature. The system is not at equilibrium because Object A is colder than Object B. The system is not at equilibrium because Object B is colder than Object A.
	Object B smaller: 2 molecules	1kJ		

Name: ______________________ Date: ______________

Revisiting the Energy Cube Model (continued)

Part 2: Revisiting the Energy Cube Model

Goal: Demonstrate what happens when a warmer object comes into contact with a colder object.

Reminders:

- Object A has 6 molecules and Object B has 2 molecules.
- Partners work together to transfer energy between the molecules of the two objects.
- The cubes represent kinetic energy.

What happens when a warmer object comes in contact with a colder object?

1. Set up the energy cubes according to the starting KE numbers indicated in the data table below for Trial 1. Make sure to use all 32 of your energy cubes.
2. Imagine that Object A and Object B have been pushed into contact.
3. Transfer kinetic energy until the system is at equilibrium.
4. With your partner, complete the last two columns of the data table below.
5. Repeat steps 1–4 for Trial 2.

Trial	Object	Starting average KE (temperature)	Starting total KE (thermal energy)	Ending average KE (temperature)	Ending total KE (thermal energy)
1	Object A (warmer) larger: 6 molecules	5kJ	30kJ		
	Object B (colder) smaller: 2 molecules	1kJ	2kJ		
2	Object A (colder) larger: 6 molecules	1kJ	6kJ		
	Object B (warmer) smaller: 2 molecules	13kJ	26kJ		

When you have completed Trials 1 and 2, discuss the following questions with your partner:

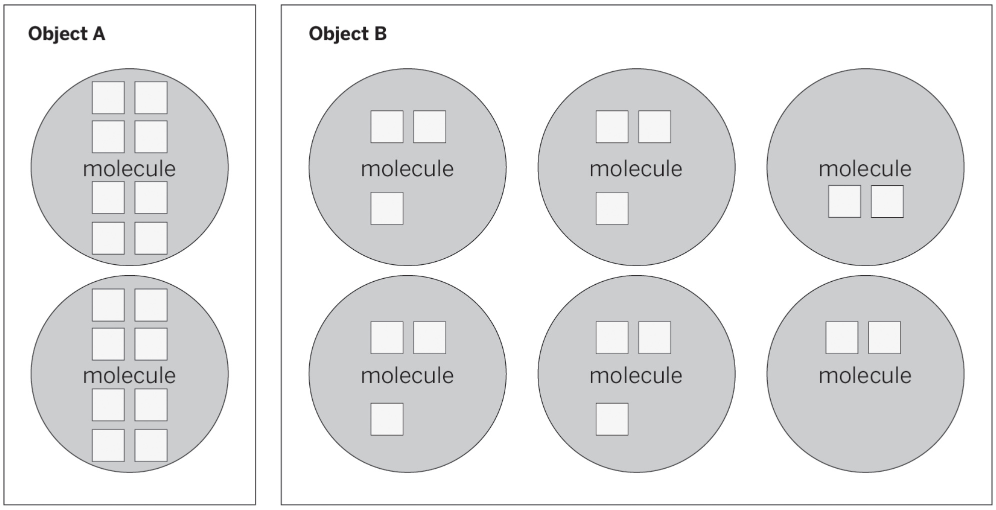
- How was what happened in Trial 1 similar to what happened in Trial 2?
- How was what happened in Trial 1 different from what happened in Trial 2?

Name: ______________________ Date: ______________

Homework: Correcting Your Friend

Your friend Jack was using the Energy Cube Model in class. Read about his model and answer the question below.

Jack's Model with Object A and B in Equilibrium



Jack's model includes one object consisting of two molecules and one object consisting of six molecules. He put 16 energy cubes in each object and stated that his model showed the two objects at equilibrium.

Explain what is wrong with Jack's model.

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Name: ______________________________ Date: ________________

Lesson 3.3: Temperature Change and Equilibrium

The principal is waiting for you to make your recommendation. Which heating system should they install at the school? How can you determine how much each heating system would warm the school? Today, you'll gather the last pieces of evidence from a demonstration and the Sim to help make an educated, evidence-based recommendation.

Unit Question

- Why do things change temperature?

Chapter 3 Question

- Which heating system will warm the air in the school more?

Key Concepts

- For things at the same temperature, the thing with more molecules has more total kinetic energy (thermal energy) than the thing with fewer molecules.
- At equilibrium, the average kinetic energy (temperature) of the molecules in the system is the total kinetic energy (thermal energy) evenly divided by the number of molecules in the system.
- When a thing gains or loses energy, the energy gained or lost is divided among all the molecules of the thing.

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- thermal energy
- transfer

Digital Tools

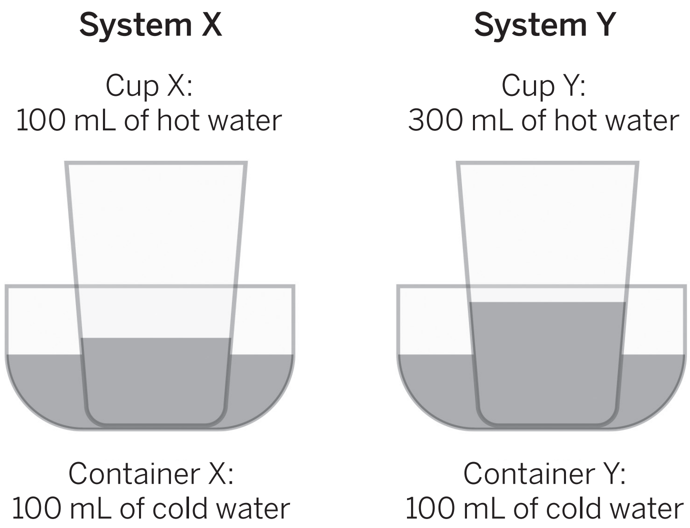
- *Thermal Energy* Simulation
- Data Tool activity: Thermal Energy vs. Temperature

Name: ______________________________ Date: ________________

Warm-Up

Predicting Changes in Water Samples

Today, you will see a demonstration of energy transfer that uses the setup pictured below. Look over the diagram and decide whether you agree or disagree with the predictions below.



Write whether you **agree** or **disagree** with each statement below.

____________ 1. The water in Cup X will end up at the same temperature as the water in Container X.

____________ 2. The water in Cup Y will end up at the same temperature as the water in Container Y.

____________ 3. All of the water in both containers and cups will end at the same temperature.

Name: ____________________________ Date: ________________

Simulating the Demo

Follow the instructions to simulate the demonstration. When you have finished both trials, answer the questions below.

System X: 100 mL cold water, 100 mL hot water

1. In the *Thermal Energy* Simulation, add a **medium** sample (Sample A) to represent the water in Container X. Cool this sample to 4.5ºC.
2. Add a **medium** sample (Sample B) to represent the water in Cup X. Warm this sample to 38.6ºC.
3. Record the Starting Thermal Energy of both samples in the table below.
4. Add the Starting Thermal Energy of both samples together to calculate the Starting Thermal Energy of the system.
5. Pull the samples into contact. When energy stops transferring, fill out the rest of the table.

System X	Sample A	Sample B	System
Starting temperature (°C)	4.5	38.6	
Starting thermal energy (kJ)			
Ending temperature (°C)			
Ending thermal energy (kJ)			

System Y: 100 mL cold water, 300 mL hot water

1. Add a **medium** sample (Sample A) to represent the water in Container Y. Cool this sample to 4.5ºC.
2. Add a **large** sample (Sample B) to represent the water in Cup Y. Warm this sample to 38.6ºC.
3. Record the Starting Thermal Energy of both samples in the table below.
4. Add the Starting Thermal Energy of both samples together to calculate the Starting Thermal Energy of the system.
5. Pull the samples into contact. When energy stops transferring, fill out the rest of the table on the next page.

Name: ______________________ Date: ______________

Simulating the Demo (continued)

System Y	Sample A	Sample B	System
Starting temperature (°C)	4.5	38.6	
Starting thermal energy (kJ)			
Ending temperature (°C)			
Ending thermal energy (kJ)			

In both systems, how did the starting thermal energy compare to the ending thermal energy of the system?

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Which system reached a higher equilibrium temperature? (circle one) **System X** **System Y**

Why do you think this system reached equilibrium at a higher temperature?

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Name: ______________________ Date: ______________

Solving the Heating System Question

Simulating the Heating Systems

Use the Sim to answer the Chapter 3 Question: *Which heating system will warm the air in the school more?* With a partner, run two separate tests and compare the results, then write your answer to the question below.

Test 1: Water heater system

1. In the *Thermal Energy* Simulation, add a large sample to represent the air inside the school. Cool this sample to 11.4º C.
2. Add a small sample to represent the water in the water heater. Warm this sample to 38.6º C.
3. Pull the samples together to find out the equilibrium temperature and record it below.

Test 2: Groundwater system

1. Add a large sample to represent the air inside the school. Cool this sample to 11.4º C.
2. Add a large sample to represent the groundwater. Warm this sample to 29.5º C.
3. Pull the samples together to find out the equilibrium temperature and record it below.

Test	**System name**	**Tank size**	**Water temperature (ºC)**	**Equilibrium temperature (ºC)**
1	water heater	small sample	38.6	
2	groundwater	large sample	29.5	

Based on your findings in the Sim, which system will warm the school more during the winter? Why will this heating system warm the school more?

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Name: ______________________________ Date: ________________

Homework: Revisiting the Anticipation Guide

Below is a statement from the Anticipation Guide that you completed at the beginning of this unit on page 6. Look back at the statement and decide whether you agree or disagree with it at this point. If you changed your mind since the beginning of the unit, then change your answer to show your current thinking. Then, try revising the statement to make it more complete or correct.

Hotter things have more energy than colder things. (check one)

☐ agree

☐ disagree

How could you revise this statement to be more complete or correct?

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Name: ______________________________ Date: ________________

Homework: Reading "Dumpling Dilemma: Oil or Water?"

As you read the article "Dumpling Dilemma: Oil or Water?," annotate it with your own ideas and questions. When you have finished, answer the question below.

What are two reasons why dumplings cook faster in oil than in water?

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What is something new you learned about temperature and thermal energy from reading this article?

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Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ____________________

Lesson 3.4: Recommending a Heating System

It is time to make a recommendation to the principal of Riverdale School! Before writing your recommendation, you'll prepare by making models that show differences in temperature change. Then, you'll get ready to write by using reasoning to explain how the evidence supports a claim about the groundwater system. Finally, you'll write your recommendation to convince the principal, Mr. Chang, that the groundwater system will work best so that he will choose the best heating system.

Unit Question

- Why do things change temperature?

Chapter 3 Question

- Which heating system will warm the air in the school more?

Key Concepts

- For things at the same temperature, the thing with more molecules has more total kinetic energy (thermal energy) than the thing with fewer molecules.
- At equilibrium, the average kinetic energy (temperature) of the molecules in the system is the total kinetic energy (thermal energy) evenly divided by the number of molecules in the system.
- When a thing gains or loses energy, the energy gained or lost is divided among all the molecules of the thing.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of the system as it decreases in another part of the system. The total energy of a system doesn't change.

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- thermal energy
- transfer

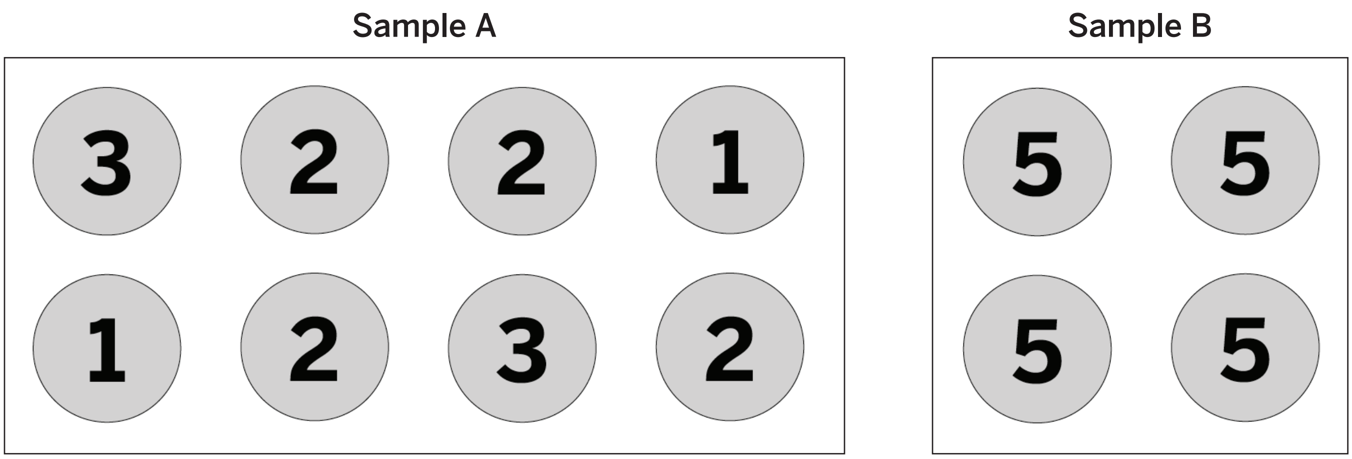
Name: ____________________ Date: ____________

Warm-Up

Calculating Total and Average Kinetic Energy

Review the system shown and answer the questions below.

These objects have just been pushed together.



What is the total kinetic energy of the molecules in this system (Sample A + Sample B) at the moment shown in the diagram above? ____________

What will the total kinetic energy of the molecules in this system be when the system reaches equilibrium? ____________

What will the average kinetic energy of the molecules in this system be when it reaches equilibrium?

____

Name: ______________________________ Date: ________________

Modeling Differences in Temperature Change

Modeling Objects of Different Sizes

Use the Modeling Tool: Differences in Temperature Change sheet to help you show the equilibrium temperatures of different systems.

Goal: Create models that show how the number of molecules in the objects of a system affects changes in temperature.

Do:

- In Modeling Differences in Temperature Change: Part 1, model how Sample A and Sample B will change temperature over time.
- In Modeling Differences in Temperature Change: Part 2, model how Sample C and Sample D will change temperature over time.

Tips:

- Use the key on the right side of the sheet to help you make your models.
- Remember to use the key concepts to help you make your models.

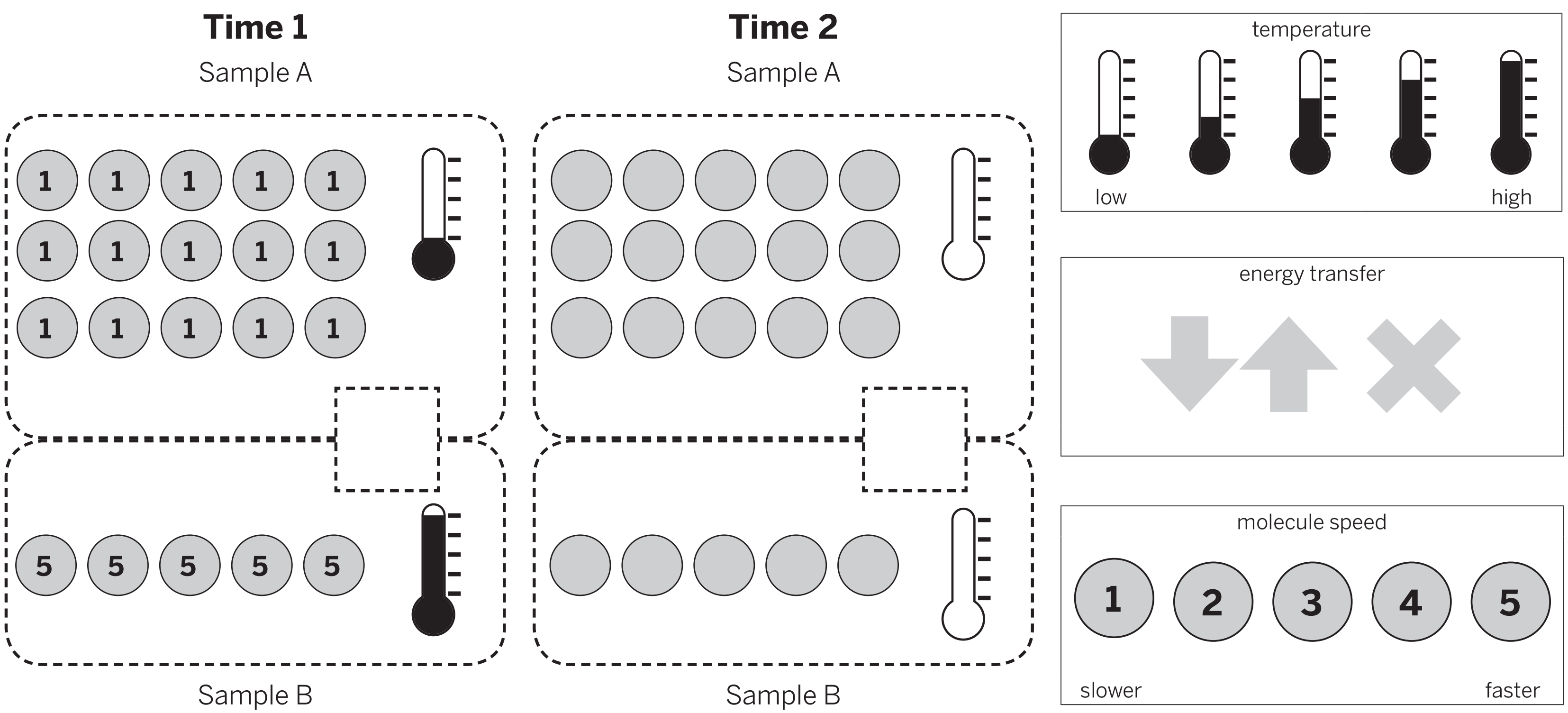
Name: ______________________ Date: ______________

Modeling Differences in Temperature Change (continued)

Differences in Temperature Change Modeling Tool

Part 1

Goal: Complete the model below to show how Sample A and Sample B will change over time.



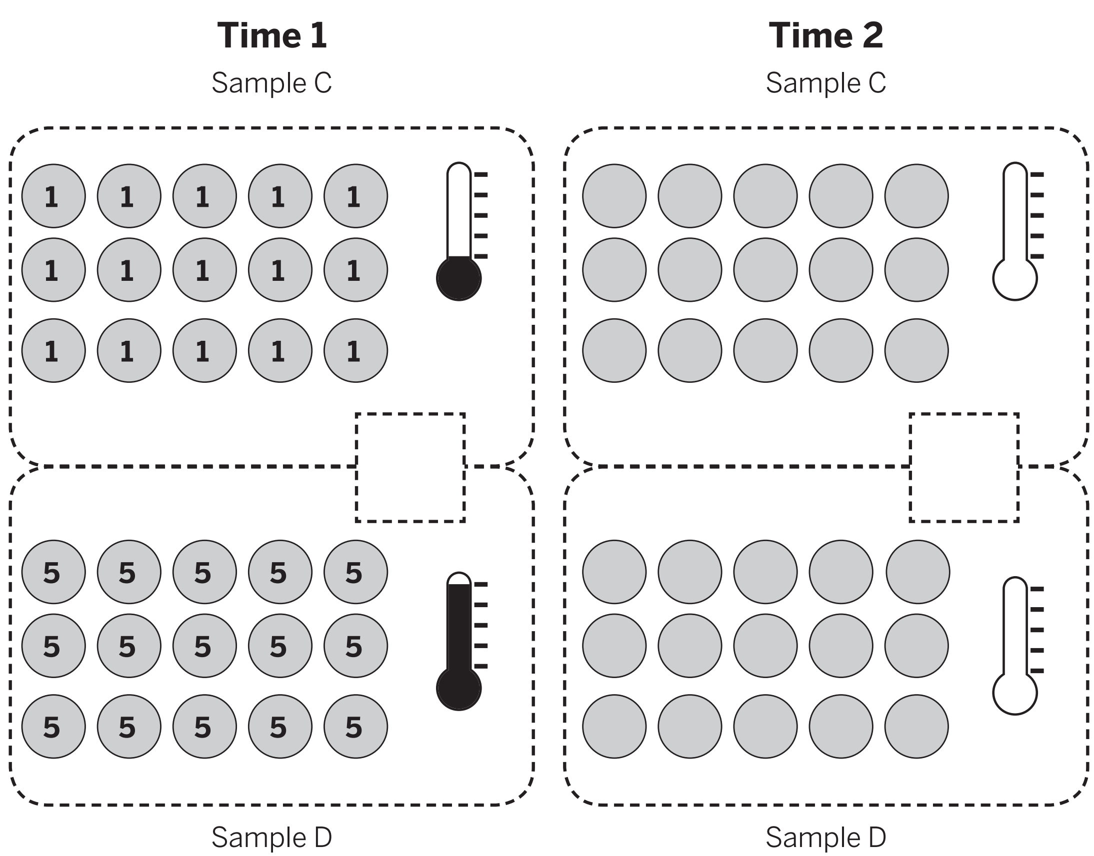
Name: ______________________ Date: ______________

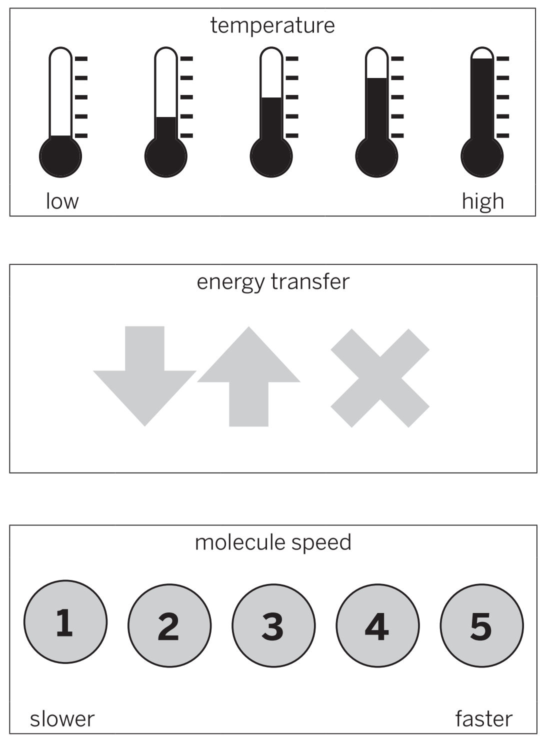
Modeling Differences in Temperature Change (continued)

Differences in Temperature Change Modeling Tool

Part 2

Goal: Complete the model below to show how Sample C and Sample D will change over time.





Name: ____________________ Date: ____________

Modeling Differences in Temperature Change (continued)

How is the model you made in Part 1 different from the model you made in Part 2?

How can you use your model to explain why the groundwater system is the better choice?

Name: ______________________________ Date: ________________

Reasoning About the Groundwater System

Making Reasoning Clearer

With your partner, choose two pieces of evidence listed in the first column of the Reasoning Tool (using the Evidence Cards for Reasoning Tool) and use the middle column to connect them to the groundwater claim.

Question: *Which heating system will warm the air in the school more?*

Claim: The groundwater system will warm the air in the school more.

Evidence	**This matters because . . .**	**Therefore, . . .** (claim)
Evidence source: *Thermal Energy* Sim		The groundwater system will warm the air in the school more.
Evidence source: "Thermal Energy Is NOT Temperature" article		
Evidence source: Energy Cube Model		
Evidence source: Thermal Energy and Size Demo		

Name: ______________________________ Date: ________________

Homework: Advising the Principal

Use the evidence you recorded in the Reasoning Tool (in the previous activity) to help you write a message to Mr. Chang recommending the groundwater heating system. You may wish to use some of the vocabulary words listed in the Word Bank and the Scientific Argumentation Sentence Starters below to help you write.

Question: *Which heating system will warm the air in the school more?*

Claim: The groundwater system will warm the air in the school more.

Word Bank

average	change	collision	equilibrium
infer	kinetic energy	molecule	stability
system	thermal energy	transfer	

Scientific Argumentation Sentence Starters	
Describing evidence:	**Describing how the evidence supports the claim:**
The evidence that supports my claim is . . .	If ____________, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since ____________, . . .
This evidence shows that . . .	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

Name: ______________________________ Date: ________________

Homework: Advising the Principal (continued)

Write a message to Mr. Chang explaining why the groundwater heating system will warm the school more than the water heater system. Use evidence to support your claim. For each piece of evidence you use, explain how the evidence supports your claim.

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out which heating system will warm the air inside Riverdale School more?

1. I understand the difference between the motion of the air molecules in the school and the air molecules in each heating system. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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2. I understand why the air in the school will change temperature when it comes into contact with water from a heating system. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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____

3. I understand what factors determine how much the motion of the air molecules in the school will change. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

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____

4. What do you still wonder about which heating system will warm the air in the school more?

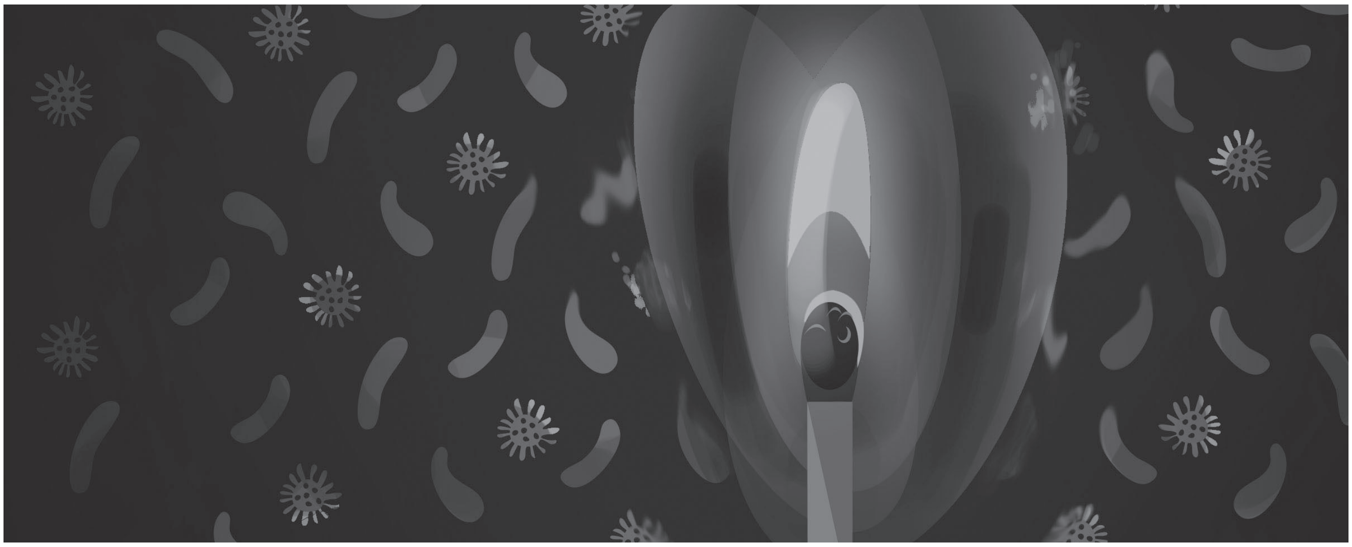
____

____

Name: ______________________________ Date: ____________________

Chapter 4: Water Pasteurization
Chapter Overview

Great job solving the question of the school heating systems! In this chapter, you'll face a new challenge: figuring out why a water pasteurization kit failed to make water safe for drinking. Pasteurize Our Water (POW) kits were distributed in the aftermath of a natural disaster on Louis Island and should have made water safe to drink, but some people still got sick. You'll use what you've learned about temperature, thermal energy, and energy transfer to examine the evidence and make an argument about what went wrong.



Name: ______________________ Date: ______________

Lesson 4.1: Pasteurizing Water in an Emergency

Student thermal scientists, you have made your recommendation to Mr. Chang, and the students and teachers of Riverdale School are grateful. Now, there's another problem that urgently needs your attention. After a natural disaster, an aid organization has been handing out kits that heat water to make it safe to drink, but some people are worried because the kits don't always seem to work. The aid organization needs you to help them analyze the evidence and figure out what could have gone wrong. Time to dive in!

Unit Question

- Why do things change temperature?

Chapter 4 Question

- Why wasn't the water pasteurized?

Key Concepts

- Things are made of molecules (or other types of atom groups).
- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.
- When two things are in contact, their molecules collide, and kinetic energy transfers from the faster-moving molecules to the slower-moving molecules.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of the system as it decreases in another part of the system. The total energy of a system doesn't change.
- The molecules of a system will transfer energy until the system reaches a stable state known as equilibrium, in which all of the molecules are moving at about the same speed.
- For things at the same temperature, the thing with more molecules has more total kinetic energy (thermal energy) than the thing with fewer molecules.
- At equilibrium, the average kinetic energy (temperature) of the molecules in the system is the total kinetic energy (thermal energy) evenly divided by the number of molecules in the system.
- When a thing gains or loses energy, the energy gained or lost is divided among all the molecules of the thing.

Name: ______________________________ Date: ______________

Lesson 4.1: Pasteurizing Water in an Emergency (continued)

Vocabulary

- average
- change
- claim
- collision
- equilibrium
- evidence
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- thermal energy
- transfer

Name: ______________________________ Date: ____________________

Warm-Up

For the next three lessons, you will be investigating a case that involves pasteurization. *Pasteurization* is the process of heating a liquid to a high enough temperature that harmful bacteria are destroyed.

Pasteurization is named after Louis Pasteur (1822–1895), the French chemist and microbiologist who discovered it.

Why do you think it might be important to pasteurize certain liquids?

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Name: ______________________ Date: ______________

Water Emergency on Louis Island

Read the news report below.

LOUIS ISLAND — An organization involved in the emergency response effort on Louis Island desperately searches for answers.

After Hurricane Nora made landfall along the coast last week, many people on Louis Island were stranded without access to clean drinking water. An organization called Pasteurize Our Water (POW) quickly developed and distributed free pasteurization kits to help people on the island make their own clean water. These kits are designed to heat water to a high enough temperature that any harmful bacteria are killed, making the water safe to drink.

The people of Louis Island used the pasteurization kits until some residents got sick, reporting symptoms like stomach pain, diarrhea, vomiting, and fever. People became concerned that POW's pasteurization kits might not be heating the water to a high enough temperature to kill harmful bacteria present in the water.

Name: ______________________________ Date: ________________

Water Emergency on Louis Island (continued)

Why Wasn't the Water Pasteurized?

The people at Pasteurize Our Water have asked you to investigate what went wrong on Louis Island. They want to know why the water did not get hot enough for the harmful bacteria to be killed.

Question: *Why wasn't the water pasteurized?*

Claim 1: If you follow the instructions, the POW kits **will always** heat the water above the correct temperature for pasteurization (65°C), but some people didn't follow the instructions.

Claim 2: Even if you follow the instructions, the POW kits **will not** heat the water above the correct temperature for pasteurization (65°C).

Pasteurize Our Water has provided you with the instructions that they included with the kits. Examine the information and discuss it with your partner. Consider the following questions:

- How does this kit use energy from the fire to heat the water?
- What ideas do you have about what might have gone wrong?

Name: ______________________________ Date: ____________________

Analyzing the Evidence

Pasteurize Our Water's investigators have collected some evidence for you to analyze. Read and annotate the Science Seminar Evidence Cards. Use the following questions to guide you as you analyze each card:

- What questions do you have about the information on the card?
- Can you use what you know about temperature and energy to explain the evidence?
- What does the evidence tell you about why the water wasn't pasteurized?

When you have finished annotating the cards, share your annotations with your partner. Use the suggestions below to guide your discussion:

- Discuss the annotations and questions you had about the Science Seminar Evidence Cards. If possible, answer each other's questions.
- Are there any two pieces of evidence that you think could work together? How do you think these two cards are connected to each other?

Name: ______________________________ Date: ______________

Sorting Evidence

1. Place the Science Seminar Question at the top of your desk.
2. Place the two claims side-by-side, underneath the question.
3. With a partner, discuss whether or not each piece of evidence supports or refutes one of the claims. Use the sentence starters below to help you discuss these claims with your partner.
4. Add new annotations to each evidence card.
   - If the evidence supports a claim, write "Supports Claim 1 *or* 2" on that card.
   - If the evidence refutes a claim, write "Refutes Claim 1 *or* 2" on that card.
   - If the evidence connects one evidence card with another, write "Connects with Evidence Card A, B, C, D, *or* E" on that card.
5. Sort the evidence by placing the cards under the claim they support.

Sentence Starters
I think this evidence supports this claim because . . .
I don't think this evidence supports this claim because . . .
I agree because . . .
I disagree because . . .

Name: ________________________ Date: ______________

Lesson 4.2: Discussing the POW System

Some residents of Louis Island have gotten sick from unclean drinking water. Pasteurize Our Water (POW) wants to find out if there are problems with its pasteurization kit so that they can fix it if necessary. In today's Science Seminar, you and your fellow student thermal scientists will discuss the evidence, listen to one another's ideas, and try to make the best argument about why the water was not pasteurized.

Unit Question

- Why do things change temperature?

Chapter 4 Question

- Why wasn't the water pasteurized?

Key Concepts

- Things are made of molecules (or other types of atom groups).
- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.
- When two things are in contact, their molecules collide, and kinetic energy transfers from the faster-moving molecules to the slower-moving molecules.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of the system as it decreases in another part of the system. The total energy of a system doesn't change.
- The molecules of a system will transfer energy until the system reaches a stable state known as equilibrium, in which all of the molecules are moving at about the same speed.
- For things at the same temperature, the thing with more molecules has more total kinetic energy (thermal energy) than the thing with fewer molecules.
- At equilibrium, the average kinetic energy (temperature) of the molecules in the system is the total kinetic energy (thermal energy) evenly divided by the number of molecules in the system.
- When a thing gains or loses energy, the energy gained or lost is divided among all the molecules of the thing.

Name: ______________________________ Date: ________________

Lesson 4.2: Discussing the POW System (continued)

Vocabulary

- average
- change
- claim
- collision
- equilibrium
- evidence
- infer
- kinetic energy
- molecule
- reasoning
- scientific argument
- stability
- system
- temperature
- thermal energy
- transfer

Name: ______________________________ Date: ________________

Warm-Up

Revisiting the Evidence

Review your sorted Science Seminar Evidence Cards from the previous lesson. Use the evidence cards to answer the questions below.

Why wasn't the water pasteurized?

Which claim do you think is the most convincing so far? (check one)

- ☐ **Claim 1:** If you follow the instructions, the POW kits **will always** heat the water above the correct temperature for pasteurization (65°C), but some people didn't follow the instructions.
- ☐ **Claim 2:** Even if you follow the instructions, the POW kits **will not** heat the water above the correct temperature for pasteurization (65°C).

Draw a star on the evidence card that best supports your claim. Why did you choose this piece of evidence?

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Name: ______________________ Date: ______________

Preparing for the Science Seminar

Preparing a Science Seminar Argument

1. With your partner, take turns sharing which claim you think is the most convincing and why.
2. Use your Warm-Up responses and the Scientific Argumentation Sentence Starters for help.
3. Refer to the Science Seminar Evidence Cards as needed.

Why wasn't the water pasteurized?

Claim 1: If you follow the instructions, the POW kits **will always** heat the water above the correct temperature for pasteurization (65°C), but some people didn't follow the instructions.

Claim 2: Even if you follow the instructions, the POW kits **will not** heat the water above the correct temperature for pasteurization (65°C).

Name: ______________________________ Date: ________________

Participating in the Science Seminar

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: ______________________________ Date: ________________

Homework: Reflecting on the Science Seminar

Now that the Science Seminar is over, think back on the claim you selected at the beginning of the lesson. After participating in the discussion, you may have changed your mind about which claim you think is best supported. Show your current thinking by answering the questions below.

Why wasn't the water pasteurized?

Which claim do you think is the most convincing? (check one).

- ☐ **Claim 1:** If you follow the instructions, the POW kits **will always** heat the water above the correct temperature for pasteurization (65°C), but some people didn't follow the instructions.
- ☐ **Claim 2:** Even if you follow the instructions, the POW kits **will not** heat the water above the correct temperature for pasteurization (65°C).

Did the Science Seminar cause your thinking about the claims to change? Explain your answer.

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Name: ______________________________ Date: ____________________

Lesson 4.3: Writing a Scientific Argument

It's time to make your case about why the water on Louis Island wasn't pasteurized when the residents used their POW kits. Today, you will write a scientific argument, using evidence to support your chosen claim. As you prepare to write this argument, you will use the Reasoning Tool to help you clearly explain how the evidence supports your claim.

Unit Question

- Why do things change temperature?

Chapter 4 Question

- Why wasn't the water pasteurized?

Key Concepts

- Things are made of molecules (or other types of atom groups).
- When a thing gets hotter, its molecules are moving faster and have more kinetic energy.
- When a thing gets colder, its molecules are moving slower and have less kinetic energy.
- Temperature is a measure of the average kinetic energy of the molecules of a thing.
- When two things are in contact, their molecules collide, and kinetic energy transfers from the faster-moving molecules to the slower-moving molecules.
- Energy isn't created or destroyed. Therefore, as energy transfers, it increases in one part of the system as it decreases in another part of the system. The total energy of a system doesn't change.
- The molecules of a system will transfer energy until the system reaches a stable state known as equilibrium, in which all of the molecules are moving at about the same speed.
- For things at the same temperature, the thing with more molecules has more total kinetic energy (thermal energy) than the thing with fewer molecules.
- At equilibrium, the average kinetic energy (temperature) of the molecules in the system is the total kinetic energy (thermal energy) evenly divided by the number of molecules in the system.
- When a thing gains or loses energy, the energy gained or lost is divided among all the molecules of the thing.

Name: ______________________________ Date: ________________

Lesson 4.3: Writing a Scientific Argument (continued)

Vocabulary

- average
- change
- collision
- equilibrium
- infer
- kinetic energy
- molecule
- stability
- system
- temperature
- thermal energy
- transfer

Name: ______________________________ Date: ____________________

Warm-Up

Making a Convincing Argument

Kalani and Lael are students who have been comparing the total kinetic energy (thermal energy) of an iceberg to an ice cube. Read and compare their arguments. Then, answer the questions below.

Kalani's Argument

My claim is that an iceberg has more total kinetic energy (thermal energy) than an ice cube. This is because even though an iceberg is about the same temperature as an ice cube, it is also much larger, so it is made of a lot more molecules. For this reason, an iceberg will have more total kinetic energy (thermal energy) than an ice cube.

Lael's Argument

An iceberg has more total kinetic energy (thermal energy) than an ice cube because it is larger and made of more molecules. This matters because molecules move, and moving things have kinetic energy, so each molecule adds its kinetic energy to the total. Since the iceberg and the ice cube are around the same temperature, the fact that the iceberg has extra molecules means that it will have more total kinetic energy (thermal energy).

Which argument is more convincing? (circle one)

Kalani's argument

Lael's argument

What makes one argument more convincing than the other?

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Name: ______________________________ Date: ________________

Using the Reasoning Tool

Why is reasoning important?

After scientists state a claim, they connect evidence to the claim in the reasoning process. This makes their argument convincing.

Using the Reasoning Tool to Support Your Claim

1. In the right column, record the claim that you think is best supported by the evidence. You may record your own claim if you prefer.
2. In the left column, tape the evidence cards that support your claim. You do not need to use all of the evidence cards, but you should use more than one to support your claim.
3. In the middle column, record how the evidence card in the left column connects to the claim in the right column.

Evidence	**This matters because . . .** (How does this evidence support the claim)	**Therefore, . . .** (claim)

Name: ______________________ Date: ______________

Organizing Ideas in the Reasoning Tool

Using the Reasoning Tool to Support Your Claim

- Draw a circle around your strongest piece of evidence.
- Draw an X over a piece of evidence if you do not plan to use it in your argument.
- Drawn an arrow to connect two pieces of evidence if you think that they go together.

Example

Evidence	This matters because . . . (How does this evidence support the claim?)	Therefore, . . . (claim)
Example Evidence Card A	Your ideas about how the evidence supports the claim	Your claim
Example Evidence Card B	Your ideas about how the evidence supports the claim	
Example Evidence Card C	Your ideas about how the evidence supports the claim	

Name: ______________________________ Date: ________________

Writing a Scientific Argument

Write your scientific argument about the POW kits below. As you write, remember to:

- Review your Reasoning Tool. Be sure to include your strongest piece of evidence and to make a connection between pieces of evidence that go together.
- Use the Scientific Argumentation Sentence Starters to help you explain your thinking.

Scientific Argumentation Sentence Starters	
Describing evidence:	**Describing how the evidence supports the claim:**
The evidence that supports my claim is . . .	If __________, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since __________, . . .
This evidence shows that . . .	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

First, explain how water gets warmed with the POW Kit, why following the instructions is important, and how failure to follow the instructions could lead to problems.

Next, write a scientific argument that addresses the question: *Why wasn't the water pasteurized?*

1. First, state your claim.

   Claim 1: If you follow the instructions, the POW kits **will always** heat the water above the correct temperature for pasteurization (65°C), but some people didn't follow the instructions.

   Claim 2: Even if you follow the instructions, the POW kits **will not** heat the water above the correct temperature for pasteurization (65°C).

2. Then, use evidence to support your claim.
3. For each piece of evidence you use, explain how it supports your claim.

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Name: ______________________ Date: ______________

Writing a Scientific Argument (continued)

Name: ______________________ Date: ______________

Writing a Scientific Argument (continued)

Name: ______________________________ Date: ______________

Homework: Revising an Argument

1. Reread the scientific argument you wrote in class. Complete your argument, if needed.
2. Then, look for ways you could make your argument clearer or more convincing.
3. Consider reading your argument aloud or having another person read it.
4. Use the questions below to help you review your argument:
   - Does your argument clearly explain why the POW kit might or might not be able to pasteurize water?
   - Do you describe your supporting evidence?
   - Do you thoroughly explain how the evidence supports your claim?
5. Rewrite any sections of your argument that could be clearer or more convincing.

Name: ____________________ Date: ____________

Homework: Revising an Argument (continued)

Name: ______________________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that scientists need to stay open to new ideas so they can change their minds when presented with new, convincing evidence.

   ☐ yes ☐ not yet

Explain your answer choice.

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2. What are the most important things you have learned in this unit about why things change temperature?

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3. What questions do you still have?

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Thermal Energy Glossary

average: a number that summarizes a set of data and that can be computed by adding all the numbers in a list and then dividing by the number of numbers in the list

promedio: un número que resume un conjunto de datos y que se calcula sumando todos los números de una lista y luego dividiendo la suma entre la cantidad de números de la lista

bacteria: tiny organisms that are made of a single cell

bacterias: organismos diminutos que están hechos de una sola célula

change: when something becomes different over time

cambio: cuando algo se vuelve diferente con el tiempo

collision: the moment when two objects hit each other

colisión: el momento cuando dos objetos chocan entre sí

energy: the ability to make things move or change

energía: la capacidad de hacer que las cosas se muevan o cambien

equilibrium: a balanced state in which a system is stable, such as when two or more samples are at the same temperature

equilibrio: un estado balanceado en el cual un sistema está estable, por ejemplo, cuando dos o más muestras están a la misma temperatura

groundwater: water that is underground

agua subterránea: el agua que está bajo la tierra

infer: to reach a conclusion using evidence and reasoning

inferir: llegar a una conclusión usando evidencia y razonamiento

kinetic energy: the energy that an object has because it is moving

energía cinética: la energía que tiene un objeto porque se está moviendo

matter: anything that has mass and takes up space

materia: cualquier cosa que tenga masa y ocupe espacio

molecule: a group of atoms joined together in a particular way

molécula: un grupo de átomos unidos de una manera particular

Thermal Energy Glossary (continued)

pasteurize: to make something safe to eat or drink by heating it

pasteurizar: hacer que algo sea seguro para comer o beber al calentarlo

sample: a small part that is meant to show what the whole is like

muestra: una pequeña parte que sirve para mostrar cómo es el todo

stability: when something stays mostly the same over time

estabilidad: cuando algo permanece más o menos igual a lo largo del tiempo

system: a set of interacting parts forming a complex whole

sistema: un conjunto de partes que interactúan formando un todo complejo

temperature: a measure of how hot or cold something is

temperatura: una medida de qué tan caliente o frío está algo

transfer: to move from one object to another or one place to another

transferir: mover de un objeto a otro o de un lugar a otro

water heater: a heating unit that stores and warms water

calentador de agua: una unidad de calentamiento que almacena y calienta el agua

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Thermal Energy:
Using Water to Heat a School

Article Compilation

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Absolute Zero

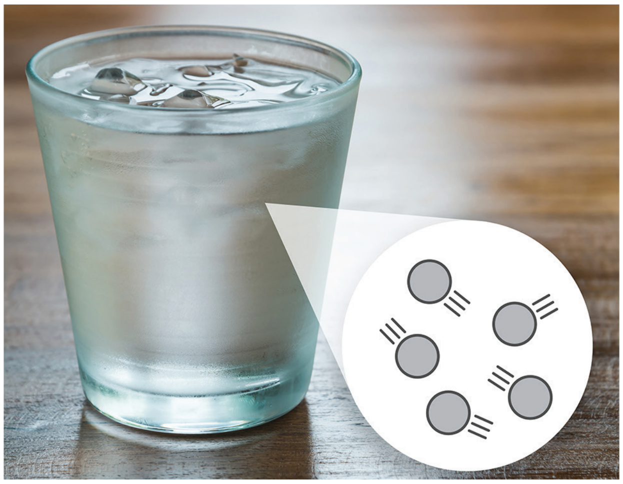
You've probably felt cold temperatures at some time in your life. Maybe you live somewhere with cold, snowy winters...or maybe you've just opened the freezer to grab a popsicle on a warm day! The temperature inside a normal kitchen freezer is around –18 degrees Celsius (0°F), but there are temperatures that get much colder than that. The coldest outdoor temperature ever recorded on Earth is –94.7°C (–135.8 °F). In space, things get even colder: scientists have measured temperatures as low as –270°C (–454°F) there.

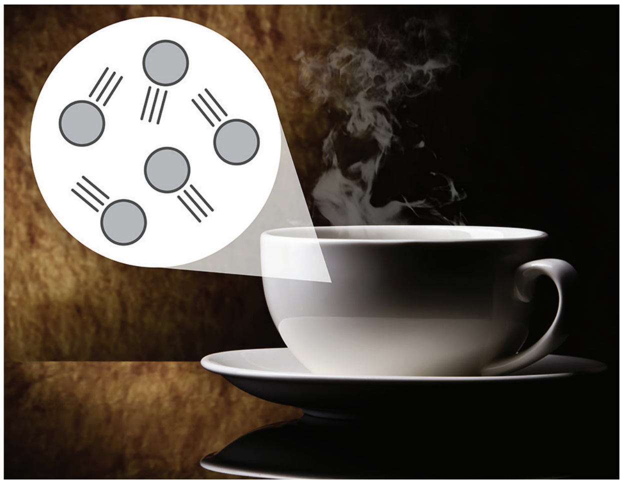
The coldest temperatures on Earth have been recorded in Antarctica.

We know that the temperature outside can feel warm or cold to us, but what is temperature actually telling us? Temperature is related to the average speed of the molecules of an object or material. Molecules are constantly moving around. When an object's molecules move at faster speeds, the object has a higher temperature. When an object's molecules move at slower speeds, the object has a lower temperature.

Is there a limit to how cold things can get? Yes! This is because temperature is determined by average molecular movement, and there is a limit to how slowly something can move. After all, if something slows down completely, it just stops moving.

What would happen if the molecules in a sample stopped moving entirely? If none of the molecules were moving, then the average speed of the molecules would be zero. This means that the sample would be at absolute zero, a temperature of –273.15°C (–459.67°F). Absolute zero is the coldest possible temperature—the temperature at which there is absolutely zero molecular movement. Scientists realized over 350 years ago that absolute zero could exist, but nobody has succeeded in demonstrating it. It may not be possible to reach absolute zero, but that hasn't stopped scientists from trying.





The temperature of something is determined by how fast its molecules are moving. The molecules in the cold water on the left are moving slowly, as indicated by the short motion tails on the molecules. The molecules in the hot water on the right are moving more quickly, indicated by the long motion tails on the molecules.

How Air Conditioners Make Cities Hotter

This air conditioning system sits on the roof of a building. It transfers energy out of the building's air to keep the building from getting too hot.

On a hot day, walking into an air-conditioned building feels great. You can leave all that hot air outside! Air conditioning makes the air inside a building cooler, keeping you from turning into a sweaty mess during hot weather.

How do air conditioners work their magic? Air is made of molecules, and the temperature of air is all about the speed of its molecules. Differences in air temperature are caused by differences in the energy of the molecules that make up the air—and the amount of energy those molecules have has to do with how fast they're moving. Air conditioners cool air by slowing molecules down.

Unfortunately, the magic of air conditioning has a dark side. Air conditioners cool the air inside, but they make the air outside even hotter!

Air conditioners can actually make heat waves worse. An air conditioner uses machines and chemicals to remove kinetic energy from the molecules that make up the air inside a room. This slows the molecules down and lowers the room's air temperature. However, energy can't be created or destroyed: it can only be transferred from one place to another. The energy that was in those molecules doesn't just disappear–it gets transferred to molecules in the air outside. This causes the air outside to warm up through a series of collisions between faster and slower molecules. As faster molecules bump into slower ones, kinetic energy transfers to the slower-moving molecules, causing them to speed up. When the molecules of the air speed up, the air temperature rises.

When you run an air conditioner, you're making it hotter outside by transferring energy from the air inside a building to the air outside the building. The air inside and the air outside are two parts of one system, connected by the air conditioner—changes in one part of the system affect the other part. In fact, one study showed that on hot nights when many people in the same town run their air conditioning, the temperature outside is about 1 degree Celsius (1.8 degrees Fahrenheit) hotter in that town than it would be otherwise. This rise in temperature means people use their air conditioning even more, and it can make things even worse in cities where the climate is already hot.

This kind of energy transfer doesn't just apply to hot buildings: it also applies to hot foreheads! Have you ever been sick with a fever, and wished you could do something to feel better? When you have a fever, one way to feel some relief is to soak a washcloth in cool water and lay it across your forehead. Some of the energy from your warm skin transfers to the cool washcloth. When two things of different

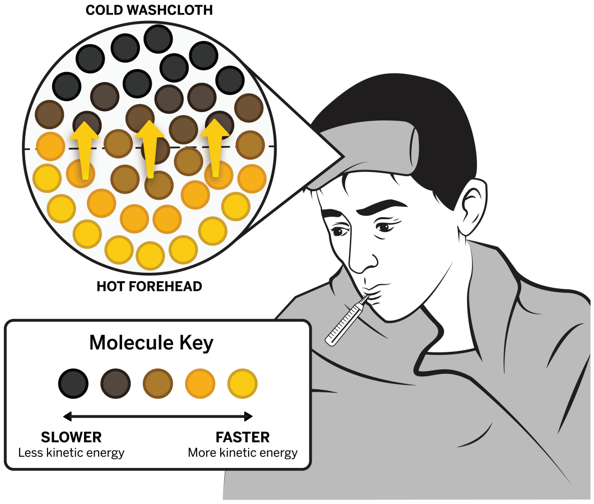
When you have a fever, placing a cool, damp washcloth on your forehead can help cool you down.

temperature come into contact, the warmer one will always transfer energy to the cooler one—in this case, your warm forehead transfers energy to the cool washcloth.

How does that transfer actually happen? Molecules are always moving, and when they collide with one another, kinetic energy is transferred from one molecule to another. The fast-moving molecules of your hot forehead bump into the slow-moving molecules of the washcloth, transferring kinetic energy from your forehead to the washcloth. Your skin cools as the molecules of your forehead slow down, while the washcloth gets warmer as its molecules speed up.

You can think of your forehead and the washcloth as two parts of the same system. Energy is transferred from one part of the system (your forehead) to another (the damp washcloth). As the temperature of your forehead drops, you feel better! However, that same washcloth won't keep you cool forever. Eventually, so much energy will transfer from your forehead to the washcloth that the washcloth and your forehead will be the same temperature, and energy will stop transferring away from your forehead. When that happens, it's time to get a new, cool washcloth so that this energy transfer can keep going and you can keep getting relief!

Whether you are cooling a room or your forehead, you need to transfer energy to do it. When one thing cools down, something else has to warm up. Since energy can't be created or destroyed, a change in temperature always means energy has been transferred—it always comes from somewhere and goes somewhere else.



As the faster-moving molecules of your hot forehead move, they bump into the slower-moving molecules of the cold washcloth, transferring kinetic energy from your forehead to the washcloth and reducing your fever.

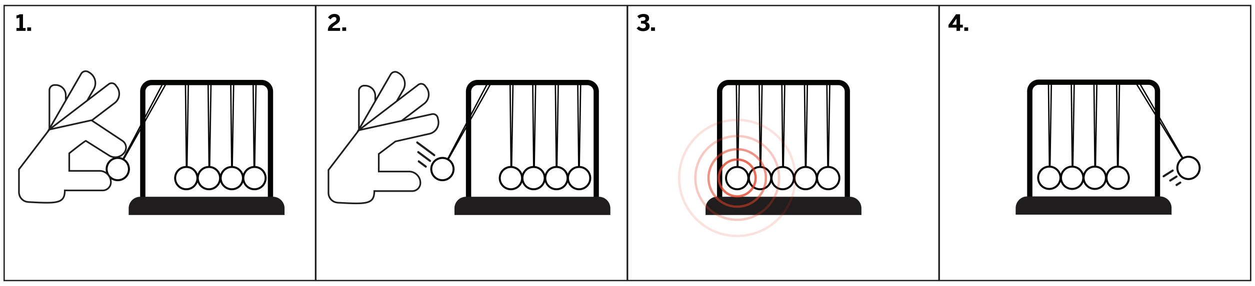
A Newton's Cradle is a toy with spheres hanging from a frame. The way energy is transferred from sphere to sphere is similar to the way energy is transferred when molecules collide.

Molecule Collisions and Newton's Cradle

Have you ever seen a toy called a Newton's Cradle? The Newton's Cradle has spheres, usually made of steel, hanging from a frame. If you pull the sphere on one end away from the others and let go, it swings back and stops when it hits the sphere next to it. Almost immediately, the last sphere on the other end of the row swings up to almost the same height that you pulled the first sphere up to. Then the last sphere swings back and stops when it hits the sphere next to it, and the first sphere swings up and out again. The two spheres on the ends keep swinging out and back, while the spheres in the middle stay in one place.

Why do the spheres on each end of the Newton's Cradle swing back and forth, while the ones in the middle stay in place? The kinetic energy the first sphere has while it swings is transferred to the next sphere in line. However, that next sphere can't move because the sphere next to it is in the way. Instead, it transfers the kinetic energy to the next sphere without moving. The energy is transferred along the line of spheres in this way until it gets to the last one, which isn't blocked by another sphere. That one swings up and away to the same height and with the same speed as the first sphere swung down, and the whole process repeats in the opposite direction. If some energy wasn't converted to thermal energy, the spheres would keep moving in this way forever, but in the real world, they do eventually slow down and stop.

The physics concepts that explain Newton's Cradle also explain the collisions between molecules. When one molecule collides with another, energy is transferred from one molecule to another and both molecules experience a change in kinetic energy—just like the spheres in the Newton's Cradle. We know they've experienced that change because they change direction or speed. However, the total amount of energy the two molecules have doesn't change. Energy can't be created or destroyed, so we know it's just transferred from one molecule to the other during the collision.



When you pull the sphere on the end of the Newton's Cradle up and then let it swing back down and collide with the sphere next to it, the sphere on the other end swings up and away.

A bowl of soup is hot because its molecules have a lot of kinetic energy.

Thermal Energy Is NOT Temperature

Imagine that you and your little brother are sitting in the kitchen on a cool autumn day. There's a pot of soup on the stove and both of you are hungry. You pour yourself a big bowl of soup, but your little brother can't eat that much, so you pour some into a small mug for him. When you go to taste the soup, however, you realize it is still too hot. You could wait for the soup to cool by itself, but you're hungry now, so you grab two identical ice cubes from the freezer. You drop one into the bowl of soup and one into the mug of soup.

Once both ice cubes have melted, you take a spoonful of soup from the bowl. The temperature is perfect—warm and hearty but not too hot. You infer that your brother's soup is the same temperature. "Have some," you say. Your brother dips his spoon into the mug, takes a sip, and makes a face. "Mine's cold," he says. At first, you think he's just complaining, but then you take a sip from his mug. It really is cold! What happened? Both the bowl of soup and the mug of soup started off at the same temperature and you added identical ice cubes to each, so why did his mug get cold while your bowl stayed warm?

Since the two containers of soup began at the same temperature, the molecules in the bowl of soup and the mug of soup started off with the same average kinetic energy. However, that doesn't mean they had the same thermal energy. Thermal energy is the *total* kinetic energy of the molecules of an object or material, and not the *average* kinetic energy. Each molecule in an object or sample adds its kinetic energy to the total kinetic energy. The bowl contains a lot more soup than the mug, and because soup is made of molecules, more soup means more molecules. Each additional molecule contributes the kinetic energy of its movement to the total kinetic energy. As a result, your bowl of soup has much higher total kinetic energy (thermal energy) than your brother's mug.

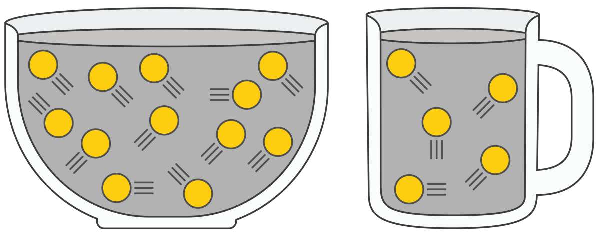
Why is this important? Well, since the two ice cubes are identical, we know that the bowl of soup and the mug of soup each have to transfer the same amount of kinetic energy to the ice to melt it. In both cases, transferring that energy to the ice makes the soup cool down. However, in the case of the mug, this transfer of energy cools the soup much more because the mug doesn't have a very high total kinetic energy to begin with. The bowl has a much higher total kinetic energy because it contains a lot more molecules, each of which adds some energy to the total. Thanks to these extra molecules, the same transfer of kinetic energy has a smaller effect on the temperature of your bowl of soup than it does on your brother's mug.

Let's say you put your brother's mug of soup in the microwave to heat it up again. Now it's very hot—much hotter than your bowl of soup. The average kinetic energy of the molecules in your brother's cup of soup is higher than the average kinetic energy of the molecules in your bowl of soup. What about the total kinetic energy (thermal energy)? Is it possible that your bowl of soup could have a lower average kinetic energy (temperature), but a higher total kinetic energy (thermal energy)? Yes! Your bowl of soup probably has a higher total kinetic energy than your brother's mug of soup because it contains more molecules. All of those molecules contribute to its total kinetic energy. To calculate the total kinetic energy of something, add up the kinetic energy of all of its molecules. So even when something has a low average kinetic energy (temperature) and isn't very warm, it can have a high total kinetic energy (thermal energy) if it has a whole lot of molecules.

Now imagine that you're waiting for your soup to cool down, and you leave it on the counter while you go do your homework. Your homework is so interesting that you forget all about your soup, and now it's cold! Actually, if you were to measure the temperature, you'd find that your soup is the same temperature as the air in the room. What's going on?

If you think of your bowl of soup and the air in the room as two parts of a system, then the explanation goes like this: Your soup is hotter and the air is cooler. Since energy always transfers from warmer things to cooler things, the kinetic energy of the molecules in your soup is transferred to the molecules in the air as the molecules collide with each other. The system continues to change—transferring kinetic energy between the soup and the air—until the soup and the air reach the same temperature (that is, their molecules have the same average kinetic energy). The soup and the air are in a stable state of equilibrium.

Your soup seems to have cooled down quite a bit, but you probably don't notice any change in the temperature of the air. This is because there are many, many more air molecules than soup molecules, so the air has a much higher total kinetic energy (thermal energy) than the soup, and you would need to transfer a lot more energy in order to change the air's average kinetic energy (temperature).Remember, thermal energy and temperature are *not* the same thing.



The bowl of soup on the left is the same temperature as the mug of soup on the right because both are made up of molecules moving at about the same speed, so they have the same average kinetic energy (temperature). However, because the bowl of soup is made up of more molecules, it has a higher total kinetic energy (thermal energy).

Dumplings that have been fried in oil have brown, crispy outsides, while dumplings that have been boiled in water are soft on the outside. Either way, they're delicious!

Dumpling Dilemma: Oil or Water?

Have you ever eaten the dumplings sometimes known as gyoza, or potstickers? These dumplings are made of meat or vegetables stuffed into thin wrappers made of dough, and they can be cooked in different ways. Boiling the dumplings in water makes the outsides of the dumplings soft, while deep-frying them in oil makes their outsides brown and crispy. Both methods involve cooking the potstickers in liquid, but the results are different: one is soft and the other is crispy. Why is that?

The difference in texture between dumplings that are boiled in water and dumplings that are deep fried in oil is due to differences in how energy is transferred into water and oil. Like all substances, water and oil each need energy transferred to them in order to heat up. However, different substances require different amounts of energy transfer to reach the same temperature. One thing you might notice if you are cooking dumplings in water is that it takes a long time just to get water to boil–much longer than it takes to heat the same amount of cooking oil to the same temperature.

Changing the temperature of water isn't easy—it takes a lot of energy. That's why it takes a long time to make a pot of water so hot that it boils: even if the burner on your stove is turned way up, a lot of energy needs to be transferred to the water before its temperature rises by even one degree. It takes much less energy to change the temperature of oil than it does to change the temperature of water, so if you transfer the same amount of energy to cooking oil and to water, the oil gets hot faster than the water does.

Substance	**Energy required to heat 1kg from 20°C to 100°C**
Water	335 kJ
Vegetable oil	134 kJ
Air	80 kJ
Sand	66 kJ

This chart shows examples of different substances and the energy required to change their temperatures from 20°C to 100°C.

There are other differences in the ways oil and water heat up: liquid water can't actually get as hot as oil can. Water boils at 100 degrees Celsius (212 degrees Fahrenheit), so that's as hot as liquid water can get—after that, it evaporates into a gas. However, oil stays liquid at 100 degrees Celsius, and can get even hotter than that without changing to a gas. This means you can cook dumplings in oil that is much hotter than liquid water can ever be.

Because liquid oil can reach such a high temperature, the outsides of the dumplings can get crispy. Since liquid water doesn't get as hot, the dumplings cooked in water stay soft when they cook. Whichever way you like to cook your dumplings, you'll have to transfer a lot of energy into them to make sure they're cooked all the way. And whether you like them soft or crispy, they're sure to be delicious!

Thermal Energy:
Using Water to Heat a School

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