The Water Cycle
Lesson 3b: Molecular Motion

Grade 5	**Length of lesson:** 45 minutes	**Placement of lesson in unit:** 3b of 6 two-part lessons on the water cycle
Unit central questions: How does water change in the world around us? Does Earth ever run out of water?		**Lesson focus question:** Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?
Main learning goal: Water is made up of molecules that move differently when water is in liquid, solid, or gaseous states.		
Science content storyline: Water is sometimes in a liquid state that we can see, sometimes in a solid state (ice) that we can see, and sometimes in a gaseous state that is spread out in the air and we can't see**.** Why is water sometimes a liquid, sometimes a solid, and sometimes a gas? Last time, we started thinking about what water molecules might have to do with these changes of state. We learned that water is made up of tiny molecules, and when these molecules are in the liquid state, they're always moving around, even when the water appears to us to be very still. Liquid-water molecules are loosely attracted to each other, allowing individual molecules to slip or slide past one another. Molecules of liquid water have more energy than molecules of solid water (ice) and less energy than molecules of gaseous water (water vapor). Molecules in the solid state behave very differently. They line up next to each other in a rigid, lattice-like formation that prevents them from moving away from each other. In the solid state, water molecules slowly vibrate in place. In the gaseous state, water molecules move apart and are not attracted to one another. The individual water molecules in a gaseous state move very fast and spread throughout the air.		
Ideal student response to the focus question: The state (form) of water depends on how its molecules are moving. When water is in the solid (ice) state, its molecules are lined up together in a rigid structure and vibrate in place. In the liquid state, the water molecules are still touching each other but are moving around more, slipping and sliding past each other in different directions. When water is in a gaseous state (water vapor), the molecules are moving much faster, and they break away from one another. They may bump into each other, but they aren't joined together or touching like solid and liquid molecules.		

Preparation

Materials Needed	**Ahead of Time**

• Science notebooks
• Chart-paper diagram of evaporation and condensation from lesson 2b
• PhET *States of Matter* simulation
• PowerPoint visuals (for use in activity follow-up):
  • 3.2 Water Molecules in Three States of Matter
  • 3.3 How Do Water Molecules Move?
Student Handouts
• 3.1 How Do Water Molecules Move? (1 per student)
	• Review the Water Cycle Content Background Document: section 1.1 (especially pages 1–5).
	• Review the PowerPoint slides and modify them as you wish.
	• Decide which optional activities you will use in the lesson.
	• Practice using the PhET *States of Matter* simulation at https://phet.colorado.edu/en/simulation/states-of-matter. First, choose "Water" from the "Atoms & Molecules" list on the right side of the screen. Then select "Solid," "Liquid," or "Gas." You can also change the temperature settings at the top of the screen. Select Celsius for temperature readings (instead of Kelvin); however, you won't need to change the setting until you use this simulation again in lesson 4a.

Lesson 3b General Outline

Time	Phase of Lesson	How the Science Content Storyline Develops
8 min	**Unit central questions/link to previous lesson:** The teacher revisits the unit central questions and links to science ideas in previous lessons.	• When liquid water is heated, it changes to water vapor (*evaporation*). • Water vapor exists in the air all around us, and we can make it change back to liquid water by cooling it (*condensation*). • Water in all three states of matter is made up of molecules. • Molecules in the liquid state are always moving around and sliding past one another.
1 min	**Lesson focus question:** The teacher introduces the focus question, *Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?*	
3 min	**Setup for activity:** The teacher introduces the PhET *States of Matter* simulation.	• We can use scientific models and reasoning to think about things we can't see, such as how water molecules move in liquid, solid, and gaseous states.
20 min	**Activity:** The teacher uses the PhET simulation to demonstrate the movement of water molecules in liquid, solid, and gaseous states. Students draw water molecules to show how they are arranged and move in each state.	• **In the liquid state,** water molecules are loosely attracted to one another, allowing individual molecules to slip or slide past one another. Liquid-water molecules have more energy than solid-water (ice) molecules and less energy than gas (water-vapor) molecules. **In the solid state,** water molecules are organized in a rigid structure that prevents them from moving away from one another; as a result, the molecules vibrate in place. Solid-water (ice) molecules have less energy than liquid-water molecules and gas (water-vapor) molecules. **In the gaseous state,** water molecules are not attracted to each other; that is, they exist individually in the gaseous (water-vapor) state. These individual water molecules move very fast all over the place. Gas (water-vapor) molecules have more energy than liquid-water and solid-water (ice) molecules.
3 min	**Follow-up to activity:** Students identify the states of matter by looking at molecular drawings in PowerPoint visuals.	
9 min	**Synthesize/summarize today's lesson:** Students write an answer to the focus question, *Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?*	• Water in all three states of matter is made up of water molecules. Water molecules behave differently in each state. • In the liquid state, water molecules can slip and slide past one another, but they're still attracted to each other, and as they accumulate in a water droplet, we can see them. • In the solid state (ice), water molecules are strongly linked together in a rigid structure, and the only way they can move is to vibrate in place. Because the molecules are clustered together, we can see them. • In the gaseous state, water molecules gain energy, so they break away from each other and are no longer attracted to one another. They exist as individual molecules that move very fast all over the place. That's why we can't see them.
1 min	**Link to next lesson:** The teacher foreshadows the next lesson.	

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8 min	**Unit Central Questions and Link to Previous Lesson** **Synopsis:** The teacher revisits the unit central questions and links to science ideas in previous lessons. **Main science idea(s):** • When liquid water is heated, it changes to water vapor (*evaporation*). • Water vapor exists in the air all around us, and we can make it change back to liquid water by cooling it (*condensation*). • Water in all three states of matter is made up of molecules. • Molecules in the liquid state are always moving around and sliding past one another.	Link science ideas to other science ideas.	**Show slides 1 and 2.** Our unit central questions are *How does water change in the world around us? Will Earth ever run out of water?* We've been studying how water changes from one state to another. What do I mean by "state"? **Show slide 3.** What do we know so far about the states of matter and how water molecules change states? **Turn and Talk (3 min):** Talk about this question with a partner, listing as many things as you can about states of matter and how they change. You can use resources like what you've written in your science notebooks, the posters we've made, and the experiments we've done. **Optional:** Have students work individually on listing as many things as they can about states of matter and how they change. **Whole-class discussion:** So what	You're talking about whether water is a solid, a liquid, or a gas.	

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		Ask questions to challenge student thinking.	ideas did you come up with? **NOTE TO TEACHER:** *Ask challenge questions and make sure to correct inaccurate ideas about states of matter. Challenge students to help in this process. Chart the accurate ideas the class comes up with.* *Make sure the following ideas are included in the list:* • *Evaporation: Adding heat energy changes liquid water to gas (water vapor).* • *Condensation: Losing heat energy (cooling) causes water vapor to change to liquid water.* • *Water in all three states of matter is made up of water molecules.* • *Water molecules in the liquid state move around.*	Liquid water can change to gas (water vapor). It's about molecules. Heating and cooling makes water molecules change states. Water molecules move. Condensation is when water vapor in the air changes back to liquid water. Cooling causes it. The water drops formed only on the cold parts of our cups.	Can you add more to that idea? Give me a complete sentence that tells what molecules have to do with how water changes states. Give me some evidence to support that statement. Is that true for all states of water? What do you know about what causes that to happen? How do you know that? What's your evidence?

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1 min	**Lesson Focus Question** **Synopsis:** The teacher introduces the focus question, *Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?*	Set the purpose with a focus question or goal statement.	**Show slide 4.** Our focus question for today is *Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?* At the end of this lesson, I'll ask you to offer a good answer to this question.		.
3 min	**Setup for Activity** **Synopsis:** The teacher introduces the PhET *States of Matter* simulation. **Main science idea(s):** • We can use scientific models and reasoning to think about things we can't see, such as how water molecules move in liquid, solid, and gaseous states.	Make explicit links between science ideas and activities **before** the activity.	Knowing more about water molecules in the three states of matter will help us answer today's focus question. When we added food coloring to cups of water, we saw some evidence that water molecules move around in liquid water. Now let's find out more about how water molecules move. Do you think water molecules move in each state of matter? How might they move differently in one state than in another state? Remember, water molecules are so tiny, we can't see them even with the most powerful microscopes. Instead,	Maybe the molecules don't move at all in solid water. Because they're frozen in place.	Why don't you think molecules move in solid water?

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			we can look at models that show us what scientists understand about how water molecules move. **Show slide 5.** In this activity, we'll watch a simulation (or model) of water molecules in liquid, solid, and gaseous states. After watching the simulation, we'll use both words and drawings to record our observations of how water molecules move. Watch closely to see how many differences you can find in the way water molecules move in liquid, solid, and gaseous states. Be thinking about how you might draw and label those movements.		
20 min	**Activity** **Synopsis:** The teacher uses the PhET simulation to demonstrate the movement of water molecules in liquid, solid, and gaseous states. Students draw water molecules to show how they are arranged and move in each state. **Main science idea(s):** • **In the liquid state,** water molecules are	Select content representations and models matched to the learning goal and engage students in their use. Make explicit links between science ideas and activities **during** the activity.	**NOTE TO TEACHER:** *Prepare to show the PhET* States of Matter *simulation depicting the movement of water molecules. Point out that each water molecule in the simulation has one orange oxygen atom and two white hydrogen atoms.* As you watch the simulation, think about how the molecules move when water is a liquid, solid (ice), or gas (water vapor). **Show the PhET simulation of water molecules in all three states of matter.**		

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	loosely connected to one another, allowing individual molecules to slip or slide past one another. Liquid-water molecules have more energy than solid-water (ice) molecules and less energy than gas (water-vapor) molecules. • **In the solid state,** water molecules are organized in a rigid structure that prevents them from moving away from one another; as a result, the molecules vibrate in place. Solid-water (ice) molecules have less energy than liquid-water molecules and gas (water-vapor) molecules. • **In the gaseous state,** water molecules are not attracted to each other; that is, they exist individually in the gaseous (water- vapor) state. These individual water molecules move very fast all over the place. Gas (water-		**NOTE TO TEACHER:** *Click on the **Solid**, **Liquid**, and **Gas** buttons on the screen to show the simulation of water molecules in each state of matter. You may want to show the simulation more than once. Then have students share their observations in a brief class discussion. Don't worry if they don't notice everything in this initial viewing. After the discussion, show the simulation again and have students make notes and drawings.* **Show slide 6.** **Whole-class discussion:** As you watched each simulation, what did you notice about water molecules in the liquid, solid, and gaseous states? What **similarities** and **differences** did you observe across the three states of matter? **ELL support:** ELL students may need help relating what they observe in the simulation to what they know about the states of matter. You may want to ask them to make connections between the behaviors of water molecules in the different states. You may also want to be explicit about what each part of the	Ice, liquid water, and water vapor are all made up of water molecules. No, just water molecules. The molecules were spread out more in the gas state.	Are they made up of anything besides water molecules? Anything else you noticed about water molecules in different states? How does that

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	vapor) molecules have more energy than liquid-water and solid-water (ice) molecules.		PhET simulation conveys so that ELLs understand it (e.g., "What does 'moving faster' represent?"). **NOTE TO TEACHER:** *Listen to see if students are noticing* • *how close together water molecules are,* • *whether molecules are touching,* • *whether molecules have a special arrangement,* • *the direction(s) the molecules are moving, and* • *how fast the molecules are moving.* **NOTE TO TEACHER ABOUT MISCONCEPTIONS:** *In most solids, molecules are closer together than in their liquid states. However, this isn't the case with water. When water is in its liquid state, the molecules are actually closer together than they are in the solid state. This is because water molecules form a crystalline structure in the solid state. This is why we observe that ice takes up more space than liquid water (it expands), and why ice floats on water. It's not important to emphasize this idea for students at this point.* **Show slide 7.**	The molecules in the solid state are touching each other. The molecules are closer together in the solid and liquid states. Molecules were moving faster in the gas state than in solid and liquid.	compare to the solid and liquid states? Can you make any other comparisons?

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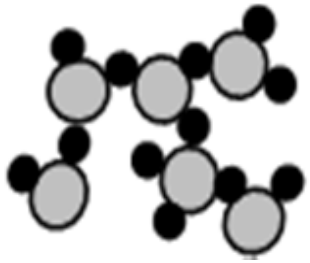
			NOTE TO TEACHER: *Distribute handout 3.1, How Do Water Molecules Move? Ask students to make some notes and draw pictures on the handout as they watch the simulation again and make more observations.* Now let's look more closely at the PhET simulation of the **liquid** state of water.  **NOTE TO TEACHER:** *Help students make the following observations from the PhET simulation:* ***In the liquid state,*** • *H_2O molecules are loosely attracted to one another.* • *H_2O molecules can move around, but they always stay in contact with other water molecules.* • *H_2O molecules have energy, so they can move around; they slip*		

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			and slide past one another. **ELL support:** Students who don't know what they're looking for may have trouble recognizing what they're supposed to notice in the simulation. In box 1 on your worksheet, draw six to eight water molecules in a liquid state. Use arrows to show how the molecules are moving. Then write a sentence or a few key words that will remind you of how water molecules move in a liquid state. What sentence or key words did you write down? **ELL support:** Allow students to think, pair, and share with a partner. **NOTE TO TEACHER:** *While students are drawing and writing sentences or key words about liquid-water molecules, do the following:* • *Walk around the room and check that students are accurately representing the molecules in terms of closeness and connections to each other.* • *Help students think about how arrows might be used to show how molecules can move only short distances before colliding*	The molecules bump each other, and sometimes they stick. They look like they're holding on to each other. They're close together.	Show me where you saw this in the simulation.

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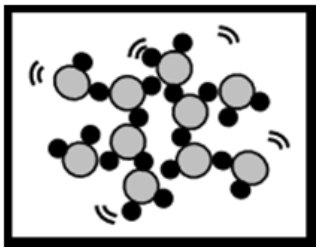
			with other molecules in the liquid state. **Turn and Talk:** Talk with a partner about how you can use what you've learned about the movement of water molecules in the liquid state to explain your observations of the food coloring in water. **NOTE TO TEACHER:** *If time is running short, skip the Turn and Talk.* **Whole-group share-out:** What did you learn about the movement of water molecules in the liquid state?		
			Now let's look more closely at the PhET simulation of the **solid** (ice) state of water.  **NOTE TO TEACHER:** *Help students make the following observations from the PhET simulation:* ***In the solid (ice) state,***		

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		Highlight key science ideas and focus question throughout.	• *H_2O molecules are held together or organized in a rigid structure.* • *H_2O molecules have less energy than H_2O molecules in the liquid state, so they don't move as much.* • *Because the H_2O molecules have energy, they vibrate in place.* In box 2 on your worksheet, draw six to eight water molecules in a **solid** state. Use arrows to show how the molecules are moving. Then write a sentence or a few key words that will remind you of how water molecules move in a solid state. What sentence or key words did you write down? **NOTE TO TEACHER:** *While students are drawing and writing sentences or key words about solid-water (ice) molecules, do the following:* • *Walk around the room and check that students are accurately representing the molecules in terms of closeness and connections to each other.* • *Help students think about how arrows might be used to show the vibration of water molecules in the solid state.*	The water molecules slow down. They join together to form a pattern. They shiver!	Show me where you saw this in the simulation.

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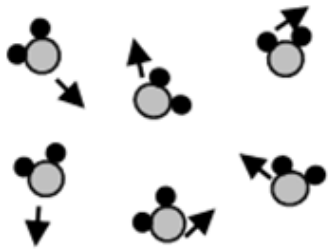
			Turn and Talk: Talk with a partner about how you can use what you've learned about the movement of water molecules in the solid state to explain your observations of the food coloring in water. **NOTE TO TEACHER:** *If time is running short, skip the Turn and Talk.* **Whole-group share-out:** What did you learn about the movement of water molecules in the solid state?		
		Highlight key science ideas and	Now let's look more closely at the PhET simulation of the **gaseous** (water-vapor) state of water.  **NOTE TO TEACHER:** *Help students make the following observations from the PhET simulation.* ***In the gaseous (water-vapor) state,*** • *H_2O molecules are separate*		

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		focus question throughout.	*from each other. They aren't in a rigid structure or even loosely attracted to other H_2O molecules.* • *H_2O molecules spread out everywhere.* • *H_2O molecules move fast in all areas of the container.* • *H_2O molecules have more energy (move faster) than liquid-water or solid-water (ice) molecules.* In box 3 on your worksheet, draw six to eight water molecules in a **gaseous** state. Use arrows to show how the molecules are moving. Then write a sentence or a few key words that will remind you of how water molecules move in a gaseous state. What sentence or key words did you write down? **NOTE TO TEACHER:** *While students are drawing and writing sentences or key words about gas (water-vapor) molecules, do the following:* • *Walk around and check that students are accurately representing the molecules in terms of movement and connections to each other.* • *Help students think about how*	The gas molecules move really fast. They aren't connected like solid and liquid molecules. They can move all over inside the container.	Show me where you saw this in the simulation.

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			arrows might be used to show that molecules in the gas (water-vapor) state can travel farther and faster before hitting other molecules. **Turn and Talk:** Talk with a partner about how you can use what you've learned about the movement of water molecules in the gaseous state to explain your observations of the food coloring in water. **NOTE TO TEACHER:** *If time is running short, skip the Turn and Talk.* **Whole-group share-out:** What did you learn about the movement of water molecules in the gaseous state?		
3 min	**Follow-Up to Activity** **Synopsis:** Students identify the states of matter by looking at molecular drawings in PowerPoint visuals. **Main science idea(s):** • **In the liquid state**, water molecules are loosely connected to one another, allowing individual molecules to slip or slide past one	Make explicit links between science ideas and activities **after** the activity. Highlight key science ideas and focus question throughout.	**Show slides 8, 9, and 10.** **NOTE TO TEACHER:** *Summarize the simulation activity with PowerPoint visuals 3.2 and 3.3 of water molecules in liquid, solid, and gaseous states. For each slide, ask students these questions:* • *What state of matter do you think these water molecules are in? Remember to answer in a complete sentence.* • *What are some key words or phrases you could use to describe water molecules in this*		

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	another. Liquid-water molecules have more energy than solid-water (ice) molecules and less energy than gas (water-vapor) molecules. • **In the solid state**, water molecules are organized in a rigid structure that prevents them from moving away from one another; as a result, the molecules vibrate in place. Solid-water (ice) molecules have less energy than liquid-water molecules and gas (water-vapor) molecules. • **In the gaseous state,** water molecules are not attracted to each other; that is, they exist individually in the gaseous (water-vapor) state. These individual water molecules move very fast all over the place. Gas (water-vapor) molecules have more energy than liquid-water and solid-water (ice) molecules.		*state of matter?* *Create a poster of key words and phrases that summarize the ideas students come up with during the discussion. This summary chart will be helpful to students as they work on the synthesize/summarize task.* **ELL support:** Key words and terms should be visible on chart paper for ELL students to refer to.		

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9 min	**Synthesize/Summarize Today's Lesson** **Synopsis:** Students write an answer to the focus question, *Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?* **Main science idea(s):** • Water in all three states of matter is made up of water molecules. Water molecules behave differently in each state. • In the liquid state, water molecules can slip and slide past one another, but they're still attracted to each other, and as they accumulate in a water droplet, we can see them. • In the solid state (ice), water molecules are strongly linked together in a rigid structure, and the only way they can move is to vibrate in place. Because the molecules are clustered together,	Highlight key science ideas and focus question throughout. Engage students in making connections by synthesizing and summarizing key science ideas.	**Show slide 11.** So let's look at our focus question again: *Why is water sometimes a liquid, sometimes a solid, and sometimes a gas?* Write an answer to this question in your notebooks, using ideas about how water molecules are arranged and move in liquid, solid, and gaseous states. **Student writing time.** ***Option:*** *If time is short, have a class discussion about the focus question instead of student writing time.* ***Embedded Assessment Task:*** *Listen to students' ideas. What's visible about student thinking?* **NOTE TO TEACHER:** *Make sure the main science ideas listed in column 2 have been included in the summary chart you created during the previous phase.*		

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	we can see them. • In the gaseous state, water molecules gain energy, so they break away from each other and are no longer attracted to one another. They exist as individual molecules that move very fast all over the place. That's why we can't see them.				
1 min	**Link to Next Lesson** **Synopsis:** The teacher foreshadows the next lesson.	Link science ideas to other science ideas.	**Show slide 12.** So now we know more about how water molecules move in different states of matter. Tomorrow we'll use these ideas to better explain how evaporation and condensation occur.		