States of Matter Lesson 1: *The Solve*

Educator's Resource Guide: Live Video Phenomenon

The Solve contains two mini lessons: The live video lesson and the animation lesson For the most comprehensive learning experience, conduct both. If you're short on time, choose one. Which lesson?

- For a more structured lesson, choose the animation.
- For a more inquiry-based lesson, choose the live video lesson (the lesson below) and assign the animation for homework.

Objective

In *The Solve*, students will:

1. Observe a phenomenon and explore an interactive simulation and investigation to construct an explanation.
2. Through these investigations, discover the concepts of states of matter.

Phenomenon Description

Most animals are unable to survive extreme cold because freezing water in their tissues prevents their cells and organs from functioning properly. But some animals, like this wood frog, are specially adapted to live in cold environments and can even tolerate the partial freezing of their bodies. How? They accumulate certain compounds called "cryoprotectants" that lower the freezing point and reduce ice formation, thus limiting freezing injury.

Time Required: 65–95 minutes

Materials Required	
• Wood frog video clip • Student Guide • Computer with speakers (for projecting video) or headphones (for student viewing on laptops) • Computers for PhET simulation and video investigation	
Safety Considerations	**Science & Engineering Practices**
None	• Developing and Using Models • Constructing Explanations or Arguments From Evidence

Inquiry Scale: Leveling Information

The Solve can be completed in various settings, including presentation-style, small groups, or individually.

Level 1: Most teacher-driven

View the video clip several times as a class. Discuss the video clip as a whole class. After the first viewing, prompt students with questions to lead them to more observations, and get them to ask questions about what they are seeing. Students will jot down observations in their Student Guide.
Explain to students that they will explore states of matter using an interactive PhET simulation to determine what causes things to freeze. Guide students as a class to complete the simulation. Next students will complete a video investigation as a class to determine what things prevent freezing. Students will respond to reflection questions and analyze data in their Student Guide with teacher support.
Students will then complete Part 4 in their Student Guide, using the information gathered to determine how changing the state of matter in the wood frog allows for its survival in freezing temperatures.

Level 2

View the video clip several times as a class. Discuss the video clip as a whole class. After the first viewing, students will work with their groups to make observations and answer reflection questions in their Student Guide. Students complete the interactive PhET simulation and video investigation, with teacher support when necessary, and in small groups or partners, work to complete Part 4 of the Student Guide.

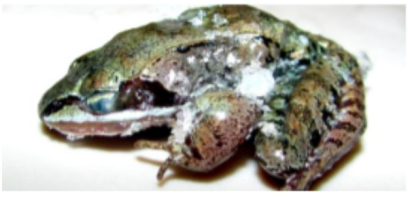
Level 3: Most student-driven

View the video clip as a class, in groups, or in pairs several times. Discuss the video clip as a whole class, and then in student groups. Students will independently respond to reflection questions in their Student Guide. Students will independently complete the Interactive PhET simulation, video investigation, and Part 4 in their Student Guide.

Agenda

Part 1. Video Clip of Phenomenon (5–10 minutes)

Differentiation Tip: The video can be viewed as a class, in small groups, individually, or completed for homework.



1. Play the live video clip of the phenomenon *The video clip is exciting and unexpected! Your students will likely react and want to watch it again. Give students time to react initially before asking them to record observations in their Student Guide.*
2. Students complete the questions in the Student Guide.
   What are your initial reactions to this video? *Answers will vary. Students might be surprised that the frog can survive this freezing temperature.*
   Play the video 2–3 more times. Students will complete the following questions after watching

the video.

Jot down 3–5 observations as you watch this video. *Answers will vary. Potential answers include: The frog appears to be frozen solid; the frog suddenly comes alive; the other animals cannot survive the same freezing temperatures.*

How do you think the frog is able to survive the freezing, then thawing? *Answers will vary. Potential answers include: The frog has a special adaptation to its environment.*

What's really going on in this video?

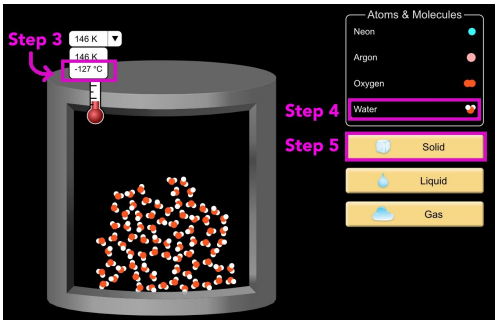
Do not yet reveal this to students as they will be discovering key components of this during their investigation!

In the harsh Arctic winter, hibernating wood frogs usually cool to temperatures that may fall to -18°C or below. When this happens, ice gradually forms in their tissues, body cavities, and blood vessels, causing their internal organs to lose water and shrink. Eventually, there is no breathing or kidney function, and the heart stops for days, weeks, and even months. But when the temperature rises again, the wood frog defrosts, wakes up, and resumes its usual activities. This adaptation to extreme cold is a result of the frog's ability to accumulate large amounts of glucose (sugar) and urea (a urinary waste product) in its blood. These compounds act as *cryoprotectants*—substances that **lower the freezing point** of the animal's tissues, **limit ice formation**, and **prevent its cells from losing too much water and freezing internally**. Ultimately, this mechanism permits the frog to survive while other animals without this mechanism would die. In this lesson, students will focus on the glucose component of the cryoprotectant system.

Part 2. Let's Explore States of Matter (15–25 minutes)

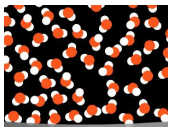
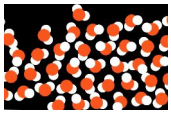
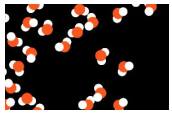
Students are going to be using an Interactive PhET Simulation: States of Matter to determine what is happening with these animals and answer the question, "What happens when things freeze?"

Student Directions

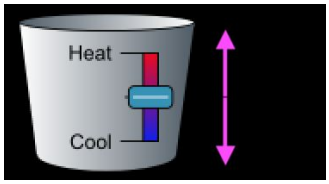


1. Click here to access the PhET Simulation on States of Matter.
2. Click on the **States** Icon.
3. Change the temperature from Kelvin (K) to Celsius (°C).
4. In the Atoms and Molecules Chart choose **Water**.
5. Click on the **Solid** button. How do water molecules behave?
   a. Sketch the arrangement of solid water molecules in the appropriate box.
   b. Record the temperature at which water is solid in the next box.
   c. Describe how the molecules move as a solid.
6. Repeat step 5 for Liquid and Gas by clicking the **Liquid** and **Gas** buttons respectively. Record data in the appropriate boxes.

PhET Simulation States of Matter Data Table

	Sketch arrangement of water molecules	**Temp. (°C)**	**Describe the motion of the molecules** (are they moving slowly, fast, very fast, etc.)
Solid		-127°C	*Water molecules are vibrating very close to each other. They are arranged in an ordered formation. They are not moving their position. Looks like they are "shivering."*
Liquid		13°C	*Water molecules are vibrating more rapidly than in the solid state. They are more spread out and individually spin and move around, bumping into one another.*
Gas		156°C	*The water molecules are moving throughout the container. They are bumping into one another in random motion. They are also spinning around randomly as individual molecules.*

7. With water already in the system, click on **Solid**.
   a. Raise the lever towards **Heat** and hold for 15 seconds. How did the increase in heat (thermal energy) change the behavior of the water molecules? *The increase in heat caused the water molecules to break their ordered structure, come together while increasing individual motion, vibrate more rapidly, and then start bumping into one another, spreading out in more random motion.*



   b. Lower the lever towards **Cool** and hold for 15 seconds. How did the decrease in heat (thermal energy) change the behavior of the water molecules? *The decrease in heat causes the water molecules to slow their motion, come very close together, and connect in an ordered structure. The vibration of the individual molecules is considerably slower.*

8. So what happens to molecules when a substance freezes? *When a substance freezes, the molecules slow down and eventually stop moving about and settle into a stable arrangement.* Tip: Point out to students that they are drawing these conclusions about water specifically, but all substances behave in this manner when they change their state of matter to solid.

Part 3. Comparing Freezing Points of Substances (20–25 minutes)

Students are now tasked with understanding what could interfere with a liquid freezing into a solid. Students will view a video that compares two liquids freezing : one is a bag of water only, the other contains a solution of water and sugar.

Experiment details:

Two bags of liquid were exposed to exposed to the same freezing temperatures in a freezer. Both bags contained XXXX mL water. One contained XXXXX g sugar.

As the video plays, students will gather observational data that shows that the water and sugar solution never freezes solid like the water-only bag. From this, they will determine that **sugar (or glucose)** can prevent a liquid from freezing solid.

In their reflection questions, students will take this discovery to the next level, applying their knowledge from the investigation to determine that frogs who are able to survive the winter have sugar (glucose) in their blood that prevents the blood from freezing solid.

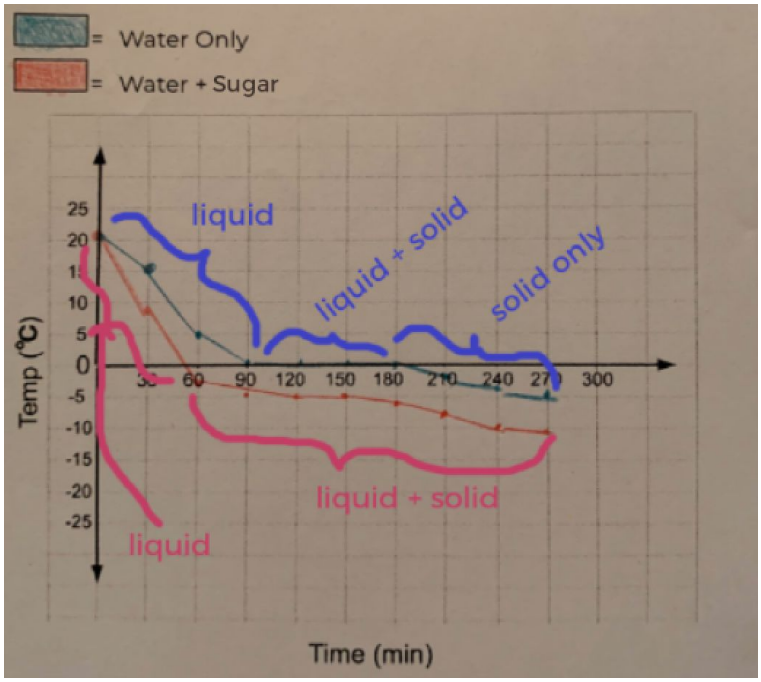
1. Show the video as a class to your students.
2. At each 30 minute (0.5 hour) mark, pause the video. Students will record the states of matter they observe in their data table.
3. Remind students that they will also be recording observational data: "liquid" when they see liquid only, "solid" when they see solid only, and "solid + liquid" if they see both.

	Water Only		Water + Sugar	
Time (hours)	Temp. (°C)	State(s) of Matter Observed *Write "Liquid," "Solid," or "Liquid and Solid"*	Temp. (°C)	State(s) of Matter Observed *Write "Liquid," "Solid," or "Liquid and Solid"*
0	*20°C*	*liquid*	*20°C*	*liquid*
0.5	*14°C*	*liquid*	*9°C*	*liquid*
1	*4°C*	*liquid*	*-2°C*	*liquid*
1.5	*0°C*	*solid + liquid*	*-3°C*	*solid + liquid*
2	*0°C*	*solid + liquid*	*-4°C*	*solid + liquid*
2.5	*0°C*	*solid + liquid*	*-5°C*	*solid + liquid*
3	*0°C*	*solid + liquid*	*-6°C*	*solid + liquid*
3.5	*-2°C*	*solid + liquid*	*-8°C*	*solid + liquid*
4	*-3°C*	*solid*	*-10°C*	*solid + liquid*
4.5	*-5°C*	*solid*	*-11°C*	*solid + liquid*

Graph Your Data

Students will use the graph and axes provided to create a *double line graph*.

Tips provided in the Student Guide: To create the double line graph, select one color to graph the data for **Water Only**. Color in the box in the Line Graph Key with your selected color. Graph each data point with this color. Then, choose a different color to represent **Water + Sugar**. Color in the box in the Line Graph Key with your selected color. Graph all data on the same set of axes. Annotate your graph by labeling directly on the graph the regions that are "liquid," "liquid + solid," and "solid."



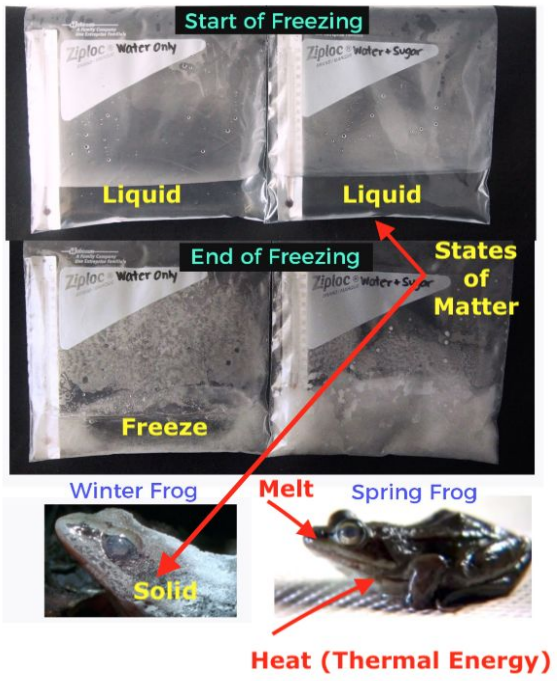
Additional tips: Advise students to begin graphing one full column of data from their data table before starting the second column. Ensure they use two colors that are easily distinguishable on a graph. Guide students to identify that temperature points above 0°C will be plotted above "0" on the temperature axis. When the temperature hits 0°C, the plots will be at "0" on the temperature axis.. Temperatures below 0°C will be plotted below "0."

Reflection Questions

1. What two substances did you analyze in the activity and how did they behave differently at zero degrees? *The two substances were "Water" and "Water + Sugar." At zero degrees, one substance (water) freezes. The other substance is a slushy liquid/frozen.*
2. Connecting this graph with the video you viewed, what could the frog have in its blood that would enable it to survive the freezing temperatures? *Sugar.*
   Tip: If students need additional support coming to this conclusion, provide question prompts: Which of the two substances tested froze solid? Which did not? Thinking about this, which would prevent the frog's blood from freezing?

Part 4. Constructing an Explanation (20–25 minutes)

1. Annotated Image: Label where you think the listed terms can be seen.



States of Matter: Conditions in which matter can exist, such as solid, liquid, or gas.
Liquid: A state of matter in which the particles are touching and are able to move freely to collide and glide past each other.
Solid: A state of matter in which molecules vibrate in fixed positions.
Melt: To change from a solid to liquid state.
Freeze: To change from a liquid to solid state.
Heat (Thermal Energy): A type of energy that results from the increased movement of particles in a solid, liquid, or gas. Heat can be transferred from one object to another.

2. Reflecting on what you learned about how things freeze and what can prevent things from freezing completely, how do you think the frog we viewed in the video is able to survive the big freeze of winter? Use as many of the terms above as possible in your answer.

Answers will vary. Potential answers include: In our experiment, we saw that adding sugar to water lowers the freezing point of water. It is likely, therefore, that the wood frog has sugar in its blood. This means it takes a lower temperature for the liquid in the frog's blood to change from a liquid into a solid. Liquid and solid are two different states of matter. In the spring, when the temperature rises, there is more heat in the air and the ice begins to melt. The frog is able to thaw out and emerge from its winter state.

Provide an opportunity for students to share out answers as a class. In addition to confirming student conclusions that the frogs must have sugar, or glucose, in their blood, now you may provide additional information about the wood frog adaptation that's provided on page 3**.**

Part 5. Exit Ticket: Check for Understanding (5–10 minutes)

Differentiation Tip: This can be done in groups, pairs, individually, or more formally as a quiz online.
Students complete the exit ticket to check for understanding. This can be done online by selecting the **Quiz** button in Lesson 1 or on paper in the Student Guide. Answers are in the Answer Key section below.

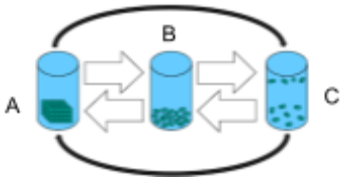
1. All of the following are true regarding solids except for:
    a. Molecules are tightly packed in a solid.
    b. Molecules vibrate at a slow speed, in a fixed position.
    c. Molecules move quickly and freely past one another in a solid.
    d. A solid has a definite shape and structure.

2. Which of the following correctly describes the action of water molecules in the wood frog's body as winter approaches and temperatures fall?
    a. Molecules gain thermal energy.
    b. Molecules change state from a liquid to a gas.
    c. Molecules increase in speed, spreading farther apart from one another.
    d. Molecules lose energy, moving closer together.

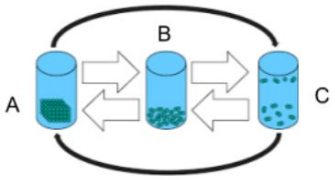
3. Which of the following states of matter consists of molecules in constant random motion:
    a. Solid
    b. Liquid
    c. Gas
    d. All of the above

4. In order for thawing and/or melting to occur:
    a. Thermal energy needs to be added to a substance.
    b. Thermal energy needs to be removed from a substance.
    c. Water in the atmosphere condenses and falls back to Earth.
    d. Temperatures must remain at 0 degrees Celsius or below.

5. Study the diagram to the right. Letter A would represent which of the following?
    a. Solid
    b. Liquid
    c. Gas
    d. Heat energy



6. Refer to the diagram. What is required for A to progress to C?
    a. Ice
    b. Heat (thermal energy)
    c. Glucose
    d. Water



7. Which of the following is true about what occurs when the frog begins to warm? **Circle all that apply.**
    a. The warmer temperature outside causes thawing.
    b. Glucose and water in the bloodstream cause cells to remain frozen solid during the thawing process.
    c. Molecules spread farther apart during the thawing process.
    d. Molecules move closer together and crystalize during the thawing process.