December, the Doorway to Winter: Surviving Freezing Temperatures

Have you ever seen a maple tree wearing a giant knit cap in the frozen winter temperatures? How about a squirrel in a sweater or a frog building a campfire? Of course not! But how do all these wild organisms survive such harsh conditions? There are really 3 main answers to this problem - migration, hibernation, and adaptation – and they all help both plants and animals make it through the darkest and coldest winter months here in the north eastern United States.

Migration is a fairly straightforward strategy to understand - it begins to get too cold in one area, so the animals travel to a warmer location until their original habitat begins to warm back up. (For more info, check out these articles on the Distance Learning Portal: Birds on the Wing, The Great Monarch Migration and its accompanying Migration Game) For the animals and plants that can't get up and go on a grand migration, the ability to slow down and/or adapt physically is essential.

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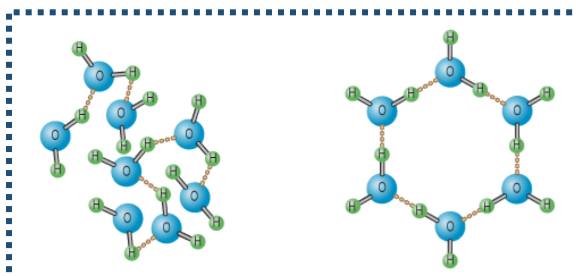
Hibernation may be the most recognizable behavior for winter survival, and typically one may think of a bear sound asleep in a cave somewhere; this image is not entirely untrue, but there are a few important corrections to note! There is a difference between **true hibernation** (when an animal's body almost completely shuts down and it is nearly impossible to wake them) and a state called **torpor** (when an animal enters a very deep and long sleep state but is still intermittently active); the latter is what a bear does down in whatever den it creates for itself! ExploringNature.com has a really extensive and interesting lesson about ways that various animals survive in winter utilizing different types of hibernation, so you'll enjoy learning more with that before checking out the activities included later in this packet!

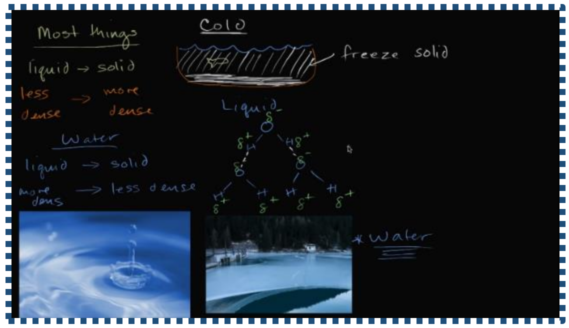


courtesy of mubirupepu.blogspot.com

Adaptation is a vital part of an organism's entire life, but when it comes to surviving extreme temperatures, some organisms have evolved in almost unbelievable ways! It all comes down to simple chemistry used in complex ways within the body of an animal and the structure of a plant. When water exists as a liquid at mild temperatures, the bonds between the water molecules are flexible and always moving around each other. As the temperature drops, the bonds become tighter and more restricted, eventually forcing the molecules to line up evenly in rigid crystalline structures, which create microscopic sharp edges all around the structure. These sharp edges pose a problem for plants and animals; the cells that make up the structures of these

Photo by Aaron Burden on Unsplash

organisms are filled with water, and when that water freezes into ice, the sharp edges puncture the soft membranes of the cells and kill them. So that is where the chemical magic happens!



This Khan Academy video lesson on the chemistry of ice formation is really useful for visually understanding what happens when water molecules form ice and how that affects the survival of animals that live in bodies of water that freeze over!

Most plants create their own food, *glucose*, through *photosynthesis* and this glucose mixes with the water inside the plant and is usually stored in its root system (let's use a sugar maple tree, *Acer saccharum,* as an example from here on). As the temperature around the tree begins to freeze at night and slightly thaw during the winter days, a natural pump system created by changes in pressure within the tree begins to move the stored sugary sap from its roots all through its trunk and limbs. The tree has developed this system because of simple chemistry: sugar mixed into water lowers the temperature at which it will freeze and form crystals, so the sugary sap acts like a natural antifreeze! Now, all the cells within the tree are at less of a risk of being pierced by the sharp edges of ice crystals because it must get much colder in order for them to form. Check out this fun video from MinuteEarth to learn more about this process and others that deciduous trees use!

This process is so effective that, believe it or not, even some animals have evolved similar adaptations! The wood frog, *rana sylvatica*, is just one of our north eastern frogs that has adapted a similar method of pulling *glycogen* from their liver, converting that to glucose, and then mixing it with *urea* (a compound found in urine that is usually filtered from the blood and expelled) in the wood frog's blood to form a similar natural antifreeze. The wood frog can settle itself in the leaf litter on the forest floor and survive becoming an actual frogsicle! When the weather warms again, it thaws out and comes back to life because its cells were protected from being shredded by ice crystals. You can see some awesome footage of this process in this video from the Smithsonian Institute channel!

There are so many incredible adaptations and behavior changes that plants and animals use to survive in the winter, this article barely scratches the icy surface, so keep a look out for more articles, lessons, and activities to learn more on the Duke Farms Distance Learn Portal!

Check out the following at-home experiment to gain a hands-on understanding of the various ways that sugar affects the freezing point of water!

Activity: Sugary Sweet: A Frozen Tree(t)!

Objective: This experiment can easily be tailored to the desired objectives of the educator and can be used to gain an understanding of how freezing affects the volume and harness of water, the effect of sugar on the freezing point of water, and the application of this chemical principal in ecology and animal/plant survival.

Materials: Many of these materials are optional and can be reconfigured in whatever combination the educator chooses.

- Water
- Sugar
- Jell-O mix
- Grapes
- Sandwich bags/plastic bags (try to upcycle used bags!)
- Upcycled plastic water bottles
- Ice cube tray
- Thermometer (food specific recommended)
- Marker
- Writing utensils and paper for recording observations

Courtesy of Thomasnet.com

Background Information: Water has a freezing point of 32°F (0°C) and is in liquid form between this temperature and its boiling temperature of 212°F (100°C). As a liquid, the water molecules have enough energy to overcome and rearrange the bonds between their atoms, which allows them to continuously bounce off each other and give water the ability to move freely in whatever container it is in. As the temperature drops, the molecules lose that energy and are no longer able to overcome the strength of those bonds, so they are forced to realign and spread out evenly into a crystalline structure. This simultaneously expands the volume that the water tapes up and creates a rigid frame that causes ice to be hard and brittle. Adding sugar to water lowers the temperature at which it freezes because the solid sugar dissolves into the liquid water and the sugar molecules mix with the water molecules; they essentially get in the way of the water molecules lining up perfectly with each other and create the need to further reduce the temperature to also freeze the sugar molecules in place. This property is utilized by plants and animals that have adapted to survive freezing temperatures (see the above article).

Procedure: The following are just examples and suggestions of ways to conduct this experiment. They can be adapted and arranged in various combinations for exemplifying whatever part of this lesson the educator desires. In each of these, it is important to allow the student to feel the sensation of the liquid vs solid forms of the various substances to gain a tactile understanding of the concept. Take the temperature of the water and mixtures at various stages to track freezing points.

- **Scenario #1** Freezing of pure water vs sugar water – Fill two containers (in which water is easily visible from all sides, such as an upcycled water bottle) with 100g of pure water. Add 50g of sugar to one container and thoroughly mix to dissolve as fully as possible. Observe the water level differences between the two containers and mark the level of each with a marker. Place both in the freezer and take note of the start time. Wait 3 hours (the standard time for most freezers to freeze water) and observe any changes to both containers with sight and touch. Compare, mark any changes, and take notes. How do they look? Has the level changed? Is one harder/more frozen than the other? Repeat every hour or so and see if any changes continue or stop happening after a certain amount of time.
- **Scenario #2** Compare the hardness of ice cubes vs grapes – Fill some cells of an ice cube tray with pure water, some with the same sugar water ratio as scenario #1, and place room temperature grapes in the rest. Place tray in freezer and wait 3-4 hours. Observe the changes and compare all the cells to each other. How did the level of the water in all the cells change? Are any of the ice cubes at different hardness levels? Are the frozen grapes as hard as the ice cubes? Do they shatter like the ice cubes?
- **Scenario #3** Compare ice to frozen gelatin – Mix a package of jello as per instructions on the package. Measure the total weight and separate in half. Allow half to set in the fridge as per instructions on the package to create solid gelatin and place the other half in the freezer in an observable container. Freeze the same amount of water in a separate container to compare. Wait 3-4 hours and observe/compare the water and liquid jello characteristics. Optional to freeze the solid gelatin after it finishes setting in the fridge. How does the hardness of all three compare?

Discussion: Would you rather squeeze an ice cube made of water or frozen jello? How does the sugar sap in a tree protect it from freezing? How does sugar in the blood stream of an animal help them survive freezing? How do humans use this process in our lives?

Student Learning Standards
The information in this article correlates directly with NJDOE Learning Standards and can be used in many different grades and content areas. For example, check into these Disciplinary Core Ideas:

Physical Science PS1: Matter and Its Interactions • PS1.A: Structure and Properties of Matter • PS1.B: Chemical Reactions PS3: Energy • PS3.A: Definitions of Energy • PS3.B: Conservation of Energy and Energy Transfer • Chemical Processes and Everyday Life

Life Science LS1: From Molecules to Organisms: Structures and Processes • LS1.A: Structure and Function • LS1.B: Growth and Development of Organisms • LS1.C: Organization for Matter and Energy Flow in Organisms • Ecosystems: Interactions, Energy, and Dynamics • LS2.A: Interdependent Relationships in Ecosystems • LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • LS2.C: Ecosystem Dynamics, Functioning, and Resilience • LS3: Heredity: Inheritance and Variation of Traits LS4: Biological Evolution: Unity and Diversity • LS4.A: Evidence of Common Ancestry and Diversity • LS4.B: Natural Selection • LS4.C: Adaptation • LS4.D: Biodiversity

Additionally, students may investigate how **climate change** may impact components of an ecosystem. To see the announcement about climate change curriculum for the state of New Jersey, a link is provided. New Jersey is the first state in the country to mandate climate change curriculum for all public schools.

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