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Snow Science: Curricular Units For High School Outdoor Winter Inquiry

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SNOW SCIENCE: CURRICULAR UNITS FOR HIGH SCHOOL OUTDOOR WINTER INQUIRY

by

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Project Summary

As a denizen of the midwest, I am quite familiar with winter. And as a Biology teacher who seeks to provide outdoor inquiry opportunities to my students, I have run into the same problem that many other midwestern teachers face: what do we do with all this snow? Winter tends to limit outdoor curricular opportunities for our students. With the ground frozen, most plants and animals are dormant, and the ecosystem appears to sleep for months. But there is life under the snow, and above it! How can teachers access this rich and forgotten source of inquiry? How can I construct curriculum for high school students to study ecology and environmental concepts through inquiry in the winter? This became the central question of my capstone project.

My goal was to create two curricular units that aligned with national science standards and incorporated as much outdoor time for students as possible. At the end of these units, I also included a project assessment in which students plan and teach a lesson about the concepts they have learned, then teach the lesson to elementary-level students.

Through research for my capstone project, I learned about the value of outdoor education, as well as of locally-focused, place-based education. Allowing students to connect and learn about the world just outside their classrooms gives them a local context for environmental issues. And teachers can accomplish this within given standards (Weise, 2012). Plus, outdoor education can have many academic benefits, including increased critical thinking skills (Ernst & Monroe, 2006) and even higher test scores (Lieberman & Hoody, 1998). So why are we staying inside?

With a national shift to the Next Generation Science Standards (NGSS Lead States, 2013) comes an increased need for lessons focused on inquiry. A few well-aligned lesson plans are available for teachers as they plan winter Biology curriculum (Hanson & Burakowski, 2015; Schon et. al., 2014), but the few lessons in these sources are not nearly enough to fill the season. With the following units, I provide teachers with a more robust resource to help fill the winter inquiry gap.

To construct these units, I used the Understanding by Design (UbD) process (Wiggins & McTighe, 2011). I designed these units “backwards”, or beginning with the Next Generation Science Standards. After selecting content standards (Disciplinary Core Ideas, or DCIs) that matched the subject of winter inquiry, I then wrote out goal statements that would allow me to assess whether or not students had mastered a particular standard. With these smaller goals in mind, I finished by writing lesson plans to help students accomplish these goals. Each lesson in these units contains both the goal statement and the associated DCI at the top of the plan. While writing the goal statements, I also made sure to include connections to Cross-Cutting Concepts (CCCs) and Science and Engineering Practices (SEPs). These are both parts of the NGSS, and goal statements in the lesson plans are color-coded to show teachers where CCCs and SEPs are built into the goals.

Written for ninety-minute block schedules, these lessons can be split into shorter lessons or extended as necessary. After the standards, the plan includes an “Opener Question” for teachers to display on the board as student walk into class. The rest of the plan utilizes a G.A.N.A.G. lesson format (Goal, Access Prior Knowledge, New

Information, Apply, and Generalize) (Pollock and Ford, 2009). Also included with the lesson plans are lab sheets (to guide students as they set up their investigations) and other materials to support teachers in providing opportunities for high-level inquiry to their students.

My hope is that this work will not only provide support and ideas for teachers, but also inspiration for students and teachers alike. Their winter world is not dead, but alive with the beauty of a dynamic creation, so intricate and worth protecting. We need to use every opportunity to teach our students about environmental stewardship, *especially* when we are all knee-deep in a good midwestern snow.

Snow Science Curricular Unit Plans (for 90-minute blocks)

Appendix

Using the Lesson Plans

The following lesson plans are aligned with the Next Generation Science Standards (NGSS). The NGSS are organized into three categories, or dimensions: Disciplinary Core Ideas (DCI), Scientific and Engineering Practices (SEP) and Cross-Cutting Concepts (CCC). All three of these dimensions were used when writing goal statements to ensure that each lesson offers students an opportunity for higher-level science learning. Standards are color-coded in these lessons to match the NGSS dimension colors and to indicate which portions of the goal statement correspond to which dimensions. For more information on the Next Generation Science Standards, please visit https://www.nextgenscience.org/.

Lesson Plan Structure

<table>
<tr><td colspan="2">Students will be able to… Also known as the goal statement, this will include color-coded sections to indicate where each of the three NGSS dimensions (DCI, CCC, and SEP) is used in the goal statement.</td></tr>
<tr><td colspan="2">Disciplinary Core Idea
Gives the selected DCI around which the lesson is based</td></tr>
<tr><td>Cross-Cutting Concepts
Lists CCCs focused on in this lesson</td><td>Science and Engineering Practices
Lists SEPs focused on in this lesson</td></tr>
<tr><td>Materials</td><td>Safety Concerns</td></tr>
<tr><td colspan="2">Opener Question</td></tr>
<tr><td colspan="2">Access Prior Knowledge</td></tr>
<tr><td colspan="2">New Information</td></tr>
<tr><td colspan="2">Apply</td></tr>
<tr><td colspan="2">Generalize</td></tr>
</table>

Lesson 0 (Long-Term Experiment Prep Day)

<table>
<tr><td colspan="2">Students will be able to design and build an animal feeder that will help them carry out an investigation of patterns in food preference for the survival of local fauna in winter.</td></tr>
<tr><td colspan="2">DCI
Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (LS4.C2)</td></tr>
<tr><td>CCC
1. Patterns
2. Cause and Effect
7. Stability and Change</td><td>SEP
● Asking Questions and Defining Problems
● Planning and Carrying Out Investigations
● Constructing Explanations and Designing Solutions</td></tr>
<tr><td>Materials
● “Food Choices” Lab Sheet
● Plastic bottles, all sizes
● Duct tape
● Scissors
● Tacks
● ¼ in wooden dowels
● Peanut Butter
● Bird Seed (2-3 types, no mix)</td><td>Safety Concerns
● Students need to be cautious when poking holes in plastic bottles. They should use a tack first to create a hole in the bottle, then poke a scissors carefully through the tack hole.

● Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.</td></tr>
<tr><td colspan="2">Opener Question
Do you have a bird feeder at home? What types of food do the birds eat from the feeder?</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Inform students that they will be spending the next couple weeks learning about winter Ecology and Environment. Make sure that they know they will need a coat, boots, mittens and hat every day for the next few weeks.

Ask students why they think birds eat seeds, peanut butter, and suet? Steer students to realize that all of these things are high in fat, and fat is both an insulator and an energy source. (https://www.audubon.org/how-do-birds-cope-cold-winter)

Based on this knowledge, ask students what type of food they think birds in this area prefer to eat in the winter?</td></tr>
</table>

New Information Explain to students that before the class starts learning about winter Ecology and Environment, we are going to set up an ongoing experiment to see if different animals prefer different food in the winter. Pass out the "Food Choices" lab sheet. Students write a hypothesis using the following sentence frame: If I provide local birds with ________ and _________ food choices, the birds will prefer the _________ because ______________________________. Students can refer to the sources below (and others) for tips on how to make a good feeder and what to put in it: ● http://www.birdsandblooms.com/birding/attracting-birds/feeding-birds/squirrel-proof-bird-feeders/ ● https://www.google.com/search?q=how+to+make+a+bird+feeder&oq=how+to+make+a+bird&aqs=chrome.2.69i57j0l5.12589j1j4&sourceid=chrome&ie=UTF-8#kpvalbx=1 ● https://blog.nwf.org/2010/12/ten-simple-tips-for-successful-winter-bird-feeding/ ● http://www.humanesociety.org/animals/resources/tips/feeding_birds.html
Apply Once students look over available sources, have them write their materials lists and procedures. Check student procedures before they begin construction of feeders. Students construct bird houses using plastic bottles, pvc pipes, and other materials available. Provide seed and peanut butter for students, but remind them to bring any other food for their experiment from home. Remind them that they may need to refill feeders occasionally and that they will be given class time to do so.
Generalize Exit Card: What issues might you encounter in your experiment? How can you adjust your experiment to minimize sources of error?

Lesson 1

Students will be able to design and carry out an experiment to look for patterns in the insulative properties of different types of snow/snow pack.	
DCI The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (ESS2.C)	
CCC 1. Patterns 2. Cause and Effect 3. Scale, Proportion, and Quantity 4. Systems and System Models 5. Energy and Matter 6. Structure and Function 7. Stability and Change	**SEP** • Asking Questions and Defining Problems • Developing and Using Models • Planning and Carrying Out Investigations • Obtaining, Evaluating, and Communicating Information
Materials • "Insulative Qualities of Snow" Lab Report worksheet • Access to computers, tablets, or laptops OR print versions of articles in "New Information" section • Small, clear disposable cups • Breakfast cereal, 3 kinds • Projector • Sticky notes	**Safety Concerns** None
Opener Question Show students the image of snowflakes under SEM in this article: https://nsidc.org/cryosphere/snow/science/formation.html Ask: "What do you think these are? How do you know?"	
Access Prior Knowledge (Students may say that they know these are snowflakes because they are blue. Remind students that the color is added to the picture so that we can distinguish between different structures.) Students share their answers with their group, then choose a group spokesperson to share the	

group's answer with the class.
Ask students: Why do snowflakes look like this? Why don't the ice cubes in your freezer come out looking like this? And how do a bunch of these packed together keep people warm?

Teacher introduces Driving Question Board to students by explaining that we will use this board to display questions that we have about winter environment. That way, we will be able to see if our questions are answered throughout the week. (For more information on Driving Question Boards, please see Weizman, Shwartz, and Fortus (2008)).

Teacher introduced driving questions for the next week:
DQB: Why do people build snow shelters to keep warm?

Students each generate 1-3 questions they have that relate to this topic and write each one on a separate sticky note. The teacher then presents the sub-questions (below) and students place their question under a sub-question that relates best to their question. Questions that students don't feel are related can go in an "other questions" category.
SQ1: How does snow keep people warm?
SQ2: Why do cold temperatures kill cells?

New Information
Students read https://nsidc.org/cryosphere/snow/science/formation.html As they read, students answer this question in their notebooks: "What happens to a snowflake (as it falls and after it hits the grounds) that determines the shape of the snowflake?" Students take turns sharing their answers with their groups. Groups generate a short list of things that determine the shape of a snowflake.

Teacher explains that she is going to model how snowflakes might look up close after they collect on the ground. She explains that we will be using cereal as a model for snow (you may want to ask students to describe *why* cereal is like snow to make sure that they understand the model). Explain that, just like the article said snowflakes can be many different sizes, different cereal types can have pieces with different sizes.

Teachers pours three different cereals into small, clear plastic cups for each group to examine. Students answer these questions in their notebooks:

Which "snowflake" type has the most air space between the pieces?

Can you arrange the pieces so that they take up more or less space in the cup? Make a sketch of the cereal pieces taking up the minimum amount of space in the cup and a sketch of the pieces taking up the maximum amount of space in the cup.

(Ideally, students will realize that if they crush the cereal, simulating melting and more densely-packed crystals, this will take up less space in the cup).

Teacher asks for each group to share their observations via a spokesperson.

Teacher asks the class: How do you think wind speed would affect the snowpack (the way the snowflakes are arranged on the ground)? Melting? Low wind conditions? (The snowpack may be more or less dense depending on weather conditions.)

Students work in groups and, using the terms for "Snow Cover" available on https://nsidc.org/cryosphere/snow/science/types.html, describe the current snowpack outside. Groups may have different answers based on where they observed the snow (sidewalk, sunny area, side of building, etc.) Let them discuss how snowpacks can be different based on location.

Teacher shows students specific heat table at (http://omp.gso.uri.edu/ompweb/doee/science/physical/chtemp6.htm) that includes water, ice, air, and common substances, reminding students that the higher the specific heat, the better the insulator.

Using the specific heat table, students answer the following questions in their groups:

Compared to other substances, are air and water good insulators?
Why do you think the air in the snowpack doesn't blow out of the snowpack?
If it can't blow out of the snowpack, where does it go? Where does the heat that it holds go?

Apply
Teacher tells students that they are going to have the opportunity to test the insulative qualities of snow. They can use beakers of warm water to simulate warm-blooded animals.

Pass out "Insulative Qualities of Snow" lab sheet. Students write a hypothesis using the following sentence frame:

"If a warm object is placed under densely-packed snow, then it will cool faster/slower (circle one) than a similar object placed under loosely-packed snow."

Once hypotheses are completed, teacher encourages students to discuss (with their lab groups) ways in which they could test this hypothesis. Remind them that their procedures need to be specific and repeatable.

Students identify the independent and dependent variables, list materials they will need, and write a procedure to test the hypothesis. Check student procedures before the end of the class.

Generalize
Exit Card: What is your "control" in your experiment? Why is this considered a control?

Lesson 2

<table>
<tr><td colspan="2">Students will be able to design and carry out an experiment to look for patterns in the insulative properties of different types of snow/snow pack.</td></tr>
<tr><td colspan="2">DCI
The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (ESS2.C)</td></tr>
<tr><td>CCC
1. Patterns
2. Cause and Effect
5. Energy and Matter
6. Structure and Function</td><td>SEP
Asking Questions and Defining Problems
Developing and Using Models
Planning and Carrying Out Investigations
Analyzing and Interpreting Data
Using Mathematics and Computational Thinking
Constructing Explanations and Designing Solutions
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information</td></tr>
<tr><td>Materials
250 mL - 500 mL beakers
Insulated Coffee carafes
Watch glass beaker covers
Warm water
Rubber beaker mitts
Thermometers</td><td>Safety Concerns
Students (and teachers) need to use rubber beaker mitts when handling and transporting hot water outdoors
Students should be told to let the teacher know if glass breaks, then clean the area carefully
Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.</td></tr>
<tr><td colspan="2">Opener Question
What materials will you need to bring outside to run your experiment?</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Remind students to check their procedures for any materials they will need to bring outdoors.

Teacher explains that she will be bringing hot water outside for experiments.</td></tr>
<tr><td colspan="2">New Information</td></tr>
</table>

Teacher reviews how to read a thermometer, how to handle the hot water, and reminds students why snow is an insulator.
Apply Students dress in appropriate winter gear and go outside to run experiments and collect data. Students return inside and add data to their lab report and write a conclusion according to the lab report format.
Generalize A spokesperson from each lab group summarizes findings to the class. During this time, encourage students to ask at least one question of each presenter. Discuss possible sources of error as a class. Lead students to the understanding that loosely-packed snow (with lots of air space in between flakes) is a good insulator for animals in the winter because trapped air cannot escape (https://nsidc.org/cryosphere/snow/science/characteristics.html). Remind them of the cereal model they created to describe the snowpack.

Lesson 3

<table>
<tr><td colspan="2">Students will be able to use a model to explain why solute concentration increases as water freezes.</td></tr>
<tr><td colspan="2">DCI
The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (ESS2.C)</td></tr>
<tr><td>CCC
1. Patterns
2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
7. Stability and Change</td><td>SEP
● Asking Questions and Defining Problems
● Developing and Using Models
● Planning and Carrying Out Investigations
● Obtaining, Evaluating, and Communicating Information</td></tr>
<tr><td>Materials
● Small Plastic Cups
● Ice Cubes
● Snow
● Magnifying glasses
● “Cytoplasm Concentration” Lab Sheet
● 250mL Beakers
● Food Coloring
● Food Choice Lab Sheet</td><td>Safety Concerns
● Students should be trained to let the teacher know if glass breaks, then clean the area carefully
● Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.</td></tr>
<tr><td colspan="2">Opener Question
Which type of snow was the best insulator yesterday? Why do you think that was?</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Teacher leads students that that more air spaces (in loosely-packed snow) provide more insulation than densely-packed snow.</td></tr>
<tr><td colspan="2">New Information
Teacher asks students what temperature they think water freezes at (in Fahrenheit AND Celsius) Students write their answers down.

Teacher asks students to stand up if they wrote that water freezes at a temperature below 100 degrees Fahrenheit. Students stay standing if they wrote that water freezes below 90 degrees...then 80, 70, and so on until all are sitting</td></tr>
</table>

Inform students that water freezes at 32 degrees Fahrenheit.
Ask students: “What is the equivalent of 32 degrees fahrenheit on the Celsius scale? Have them repeat the standing vote again as outlined above.

Inform students that water freezes at 0 degrees Celsius and 32 degrees Fahrenheit. Fahrenheit is used in healthcare (like taking a child’s temperature when they are sick) and Celsius is used in science measurements around the world. So we need to understand both of these temperature “languages”.

Inform students they will be looking at two different kinds of ice in separate cups. Students retrieve a plastic cup with an ice cube (to represent lake ice), a plastic cup with snow, and four magnifying glasses.

Students generate a list of questions (in groups) that they have about the differences between snow and ice. Encourage them to write down any question that comes to mind, and encourage them to avoid answering the questions(Example Questions: Why are there lots of air spaces between ice crystals in snow and not between ice crystals in the ice cube? What makes ice freeze in a snowflake shape? Why do the snowflakes appear in many different forms while ice cubes have a consistent shape?)

Each group picks one unique question to write on the board. Groups pick a spokesperson to read the question out loud and explain why the group selected the question.

These questions can be added to the driving question board.

Teacher tells students that, since this is Biology (the study of life) next we are going to explore how ice affects life.

Have half of the students read one article and half of the students read the other, each working to answer the question: “How does ice affect life?” individually. Students then meet with all others in the class who read the same article to collaborate. Students should then meet with someone who read the opposite article and report how their article answers this question.

https://www.scientificamerican.com/article/how-do-embryos-survive-th/

https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/animal-survival-in-extreme-temperatures.html

Remind students that cells contain lots of vital molecules in solution (cytoplasm).

How do you think the solution of cytoplasm of the cell would be affected by freezing? Do you think that freezing would change the concentration of the cytoplasm inside the cell?

Apply Pass out “Cytoplasm Concentration” Lab Sheet Students write a hypothesis using the following sentence frame: If ice forms inside of the cell, then the concentration of the cytoplasm would (increase/decrease/remain the same) Have the students prepare 2 cups of water each (one control and one for the freezer), with the same concentration of food coloring. (Note: This may work better if students prepare their solutions the day of this lesson, but do not freeze them yet. Arrange things so that cups can be put in the freezer about 3-4 hours prior to class starting, before they are frozen solid.) Students should be able to see the difference in color between the control and the frozen after the ice that is formed in the cup is removed. This lab can also be completed as a teacher demonstration if short on time. Remainder of the block can be spent outside collecting data from Food Choice Lab.
Generalize Exit Card: Students draw a model of what they think happens to a cell when it begins to freeze. Ask them to include an ice crystal, cell membrane, the nucleus, and dissolved molecules of the cytoplasm in their models.

Lesson 4

<table>
<tr><td colspan="2">Students will be able to design and carry out an experiment to test the effects of different insulators on organism temperature.</td></tr>
<tr><td colspan="2">DCI
Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (LS4.C4)</td></tr>
<tr><td>CCC
1. Patterns
2. Cause and Effect
5. Energy and Matter
6. Structure and Function</td><td>SEP
● Asking Questions and Defining Problems
● Planning and Carrying Out Investigations
● Analyzing and Interpreting Data
● Constructing Explanations and Designing Solutions
● Engaging in Argument from Evidence
● Obtaining, Evaluating, and Communicating Information</td></tr>
<tr><td>Materials
● Shortening
● Cotton balls
● Artificial feathers
● Artificial fur, cut into beaker-sized strips
● 250 mL Beakers
● 1000 mL beakers
● Paper plates
● Magnifying glasses
● “Animal Insulators” Lab Sheet
● “Food Choice” Lab Sheet</td><td>Safety Concerns
● Students should be asked to let the teacher know if glass breaks, then clean the area carefully.
● Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.</td></tr>
<tr><td colspan="2">Opener Question
Review: List two differences between an animal cell and a plant cell.</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Remind students that plant cells have a cell wall and chloroplasts (for photosynthesis) and that animal cells do not have these structures. How might these different cells respond to the formation of ice crystals inside?

Have students check ice cups, record observations, and write a conclusion. They should revise their models (exit card from Lesson 3) to indicate that solute concentrations in the cell increase</td></tr>
</table>

with the formation of ice crystals inside the cell.

Post-Lab Question (Think-Pair-Share): If the concentration of the liquid inside the cell increases, what will happen to the cell as a result?

Prompt students to remember that water flows from low concentrations to high concentrations, and that when a cell overflows, it bursts. This is what happens to tissue in the process of frostbite (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4923033/).

New Information
If cells are killed when they freeze, how do organisms living in below-freezing temperatures avoid freezing? What might help them hold their body heat in?

Prompt students to list fur, feathers, and fat as possible insulators. Connect the idea of the reduced air flow that makes snow an insulator to the idea that fur and feathers also trap air to act as insulators.

Students read the "Background" section of https://www.scientificamerican.com/article/how-do-arctic-animals-stay-warm/ and to look for patterns in the way that snow insulates and the way that fat, feathers, and fur insulate.

But how well does fat act as an insulator compared to other materials?

Pass out paper plates to each group with a spoonful of shortening, a few feathers, and a piece of artificial fur. Have students examine these with magnifying glasses to determine how they might help animals hold in heat.

Teacher hands out "Animal Insulators" Lab Sheet

Students make a list of materials that they can bring in to test for insulative qualities.

Students write a hypothesis using the following sentence frame: If two insulators are placed around beakers of hot water and placed in the snow, then the beaker surrounded by (insulator) will have a higher temperature than (other insulator) after 20 minutes.

Apply
Students write materials list and procedures to be tested the following day. Check student procedures before they begin assembling their materials. Students can prepare beakers with shortening to prepare for experiment.

Remainder of the block can be spent outside checking on Food Choice Lab

Generalize
Exit Card: What is a control? How should I set up a control in this lab? (Some groups can have a beaker with no insulator)

Lesson 5

Students will be able to design and carry out an experiment to test the effects of different insulators on organism temperature.
DCI Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the **expansion of some species**, the **emergence of new distinct species** as populations diverge under different conditions, and the **decline–and sometimes the extinction–of some species**. **(LS4.C4)**

CCC 1. Patterns 2. Cause and Effect 5. Energy and Matter 6. Structure and Function	**SEP** • Planning and Carrying Out Investigations • Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions
Materials • Shortening • Cotton balls • Artificial feathers • Artificial fur, cut into small squares (about 10x10 cm) • 250 mL Beakers • 1000 mL beakers • Food Choice Lab Sheet • Animal Insulators Lab Sheet	**Safety Concerns** • Students should be trained to let the teacher know if glass breaks, then clean the area carefully • Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.

Opener Question Physical Science Review: When a person covers themselves with a blanket, they feel warmer. Is the heat coming from the person or the blanket?
Access Prior Knowledge Teacher stands in front of class with a small blanket and explains to the class that they will be working to construct an explanation for why a blanket makes people warmer. She then sketches a diagram of a person covered with a blanket in a similar way. Students work in groups to make similar diagrams, adding a sketch or description of radiant energy in the diagram. Students nominate one person from their group to present the explanation to the class.
New Information Teacher leads class to settle on a diagram that shows radiant energy coming from the person and remaining between the person and the blanket. Connect this to the insulative properties of snow discussed in Lesson 1. Ask students how they can use this explanation in their conclusions.

Apply Students run their experiments, recording data and writing conclusions. Students will need to complete a diagram in their lab reports explaining how the radiant heat in their hot water beaker was "held in" best by the most effective insulator. Remainder of the block can be spent addressing whether or not the questions on the "Driving Question Board" were answered during the course of the past week. Ask students what questions they still have and let them know if you plan to address these questions in future units.
Generalize Exit Card: What kind of insulator worked the best? Why do you think that is?

Lesson 6 (Optional - Light Meters Needed, 1-2 blocks)

<table>
<tr><td colspan="2">Students will be able to design an experiment to look for patterns between snow density and reflectivity, as well as use these patterns to make predictions about the effects of human-caused changes to the environment.</td></tr>
<tr><td colspan="2">DCI
Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (LS4.C4)</td></tr>
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● Analyzing and Interpreting Data
● Using Mathematics and Computational Thinking
● Constructing Explanations and Designing Solutions</td></tr>
<tr><td>Materials
● Reflectivity vs Density Labs
● Light Meters
● 4 ft x 2 in PVC pipes
● Plastic sandwich bags
● Scales (for mass of snow)
● Spatulas (for covering PVC Pipes after pressed into snow)</td><td>Safety Concerns
● Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.</td></tr>
<tr><td colspan="2">Opener Question
Physical Science Review: Which color best reflects light, white or black? Why is that?</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Teacher asks students to stand if they thought that black was the most reflective. Then the teachers asks the students to stand if they thought white was the most reflective. Teacher reminds students that lighter objects reflect light best, and darker objects actually absorb light energy.

Teacher asks students to imagine an extremely hot summer day. Which would you rather stand on with bare feet- a blacktop parking lot or light concrete?</td></tr>
<tr><td colspan="2">New Information
Students will recall that blacktop is usually warmer. Let students know that this is because</td></tr>
</table>

black is a perfect absorber and white is a perfect reflector. Scientists can measure reflectivity, or albedo, on a scale from 0-1, from perfect absorbers to perfect reflectors.

Students read the following article and answer the "check your thinking" questions as a group. Group members choose a spokesperson to be ready to share answers with the class.

Teacher calls on different groups to share answers to the five questions.
http://www.sciencepartners.info/module-5-snow/albedo/

Why might it be a bad thing if a little more snow melts in the world? (This may trigger a feedback loop in which the ground becomes warmer, which melts more snow, which causes the ground to become warmer, etc.

But what about old (dense) snow vs light fresh snow? Will one of these types of snow have a higher albedo than the other?

Density is mass/volume. Ask: "How could we calculate the density of the snow?" (find the mass of a given volume of snow). Tell students they will have access to PVC pipes and scales. Encourage them to discuss these measurements with their groups.

Tell students that we can use a light meter to approximate albedo.
(For more information on using light meters in a similar experiment, visit http://cires.colorado.edu/outreach/sites/default/files/curriculum/Worksheets%20%28Module%201%29.pdf. Light meters can be used in place of more expensive equipment mentioned in http://static.nsta.org/connections/highschool/201503SnowAlbedoClimateLessonPlan.pdf)

Apply
Pass out "Reflectivity vs Density" Lab. Students write a hypothesis using the following sentence frame: If the density and albedo of the snowpack are measured in various locations, then the density will (increase/decrease) as albedo increases.

Students compile a materials list and write their procedures. You may want to demonstrate how to collect a column of snow with the PVC pipe, hold the snow in with the spatula, and put the snow into a plastic bag to bring back to the class. Check student procedures before they begin their experiments.

Students will each go to a different location and measure the density and albedo of the snow pack (two times recommended). Students can take the average of the two values and share them in a class data table. The class can then discuss the meaning of the data, along with any possible sources of error, before they write their individual conclusions.

Generalize
Exit Card: Based on what you now know about albedo and snow density, predict how continued warming affects albedo which in turn affects warming and so on. Describe how this "positive feedback loop" works and why it is important that we understand it?

Lesson 7

<table>
<tr><td colspan="2">Students will be able to design an experiment to answer a question about changes to the rate of photosynthesis in the winter.</td></tr>
<tr><td colspan="2">DCI
Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (LS1.A4)</td></tr>
<tr><td>CCC
2. Cause and Effect
3. Scale, Proportion, and Quantity
5. Energy and Matter
7. Stability and Change</td><td>SEP
● Asking Questions and Defining Problems
● Planning and Carrying Out Investigations
● Analyzing and Interpreting Data
● Using Mathematics and Computational Thinking
● Engaging in Argument from Evidence
● Obtaining, Evaluating, and Communicating Information</td></tr>
<tr><td>Materials
● Lamps
● 200 or 250mL beakers
● Hole punches
● Needleless syringes
● Bag of spinach
● Warm water and ice water
● Timers
● Rate of Photosynthesis Lab Sheet</td><td>Safety Concerns
● Students should be asked to let the teacher know if glass breaks, then clean the area carefully
● Students need to wear goggles when working with glass and hot water.
● Students need to use rubber mits to transport hot objects.</td></tr>
<tr><td colspan="2">Opener Question
DQB: Do trees freeze?</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Students each generate 1-3 questions they have that relate to this topic and write each one on a separate sticky note (see Lesson 1). The teacher then presents the sub-questions and students place their question under a sub-question that relates to their question. Questions that students don’t feel are related can go in an “other questions” category.
SQ1: If living things are mostly water, and water freezes in winter, why don’t plants and animals freeze and die in the winter?
SQ2: Do plants grow in the winter?
SQ3: How does winter affect animal behavior?</td></tr>
</table>

Teacher asks students to make a list with their groups of anything they think that plants need to do photosynthesis (this should be a review). Students nominate a group member to write one of these things on the board. Once students have their ideas written on the board, teacher writes the equation for photosynthesis. (Some students may say that oxygen or sugar is necessary for photosynthesis to occur. Explain that oxygen and sugar are byproducts of photosynthesis and that they are not directly necessary. Plants need sunlight, CO_2, and H_2O.) Have students change their lists in their notebooks accordingly. Ask students if they think it's possible for plants to photosynthesize in the winter. How could we test that?
New Information Teacher introduces "Spinach Disk" Method for comparing rates of photosynthesis: Remind students that, since oxygen is a product of photosynthesis, spinach disks that have had the air removed should float in a glass of water after photosynthesis has taken place. How can we use this method to compare rates of photosynthesis in summer temperatures and winter temperatures?
Apply Students write hypothesis using the following sentence frame: If the rate of photosynthesis is compared between warm and cold temperatures, then photosynthesis will occur faster in (warm/cold) temperatures. Teacher explains materials and some basic procedures for the lab (see Appendix) and students write a materials list and a procedure. Check students procedures before they being the experiment.
Generalize Exit Card: Many trees do not have leaves in the winter. Do you think that these trees photosynthesize in the winter? Why or why not? https://link.springer.com/chapter/10.1007%2F978-3-642-56849-7_19 https://nph.onlinelibrary.wiley.com/doi/pdf/10.1111/nph.13723 (The green layer of tissue directly under the bark contains chlorophyll and can recycle CO_2 respired from the living cells inside the plant?)

Lesson 8

Students will be able to use evidence to support a claim that a specific adaptation allows an organism to be more competitive.
DCI Ecosystems have **carrying capacities**, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the **availability of living and nonliving resources** and from such challenges such as **predation, competition, and disease**. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. **(LS2.A)**

CCC 2. Cause and Effect 5. Energy and Matter 6. Structure and Function	**SEP** ● Analyzing and Interpreting Data ● Using Mathematics and Computational Thinking ● Engaging in Argument from Evidence ● Obtaining, Evaluating, and Communicating Information
Materials ● Access to device or article printouts ● Torpor Chart	**Safety Concerns** ● Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.

Opener Question List any animals you know that hibernate.
Access Prior Knowledge Students create a list of animals in their notebooks that they think hibernate in the winter. For each animal they list, have them make a one-sentence prediction about WHY they think this animal hibernates.
New Information Students read: https://www.discoverwildlife.com/animal-facts/what-is-hibernation/. As they read, students should create a Venn Diagram to compare torpor and hibernation. Discuss the following question in groups: Why is torpor an adaptation? How does torpor help the animal survive? Groups discuss and then pick a spokesperson to summarize the thoughts of the group in 2-3 sentences. Groups share out to the class.

Hand out torpor chart. Have students note the low temperatures that some local animals drop to during torpor or hibernation. Why would it be beneficial for an animal to stay cold in the winter? (Lead students to make the connection that low body temperatures mean less energy is wasted on keeping warm.) Review with students the meaning of competition (organisms competing for available resources). What resources might the a small mammal be competing for? How does torpor help it compete?
Apply Students will select one animal on the torpor chart, look up one reliable source about the animal, and write a claim based on evidence answering the question "How does torpor allow this animal to be more fit for its environment?" Students meet with groups who wrote about the same animal to compare thoughts. Remind students that they should check their answers against the group and be willing to ask questions and critique. Groups nominate one student to summarize the following: Which term (hibernation or torpor) best describes the behavior of this animal. Why? The remainder of the hour can be spent collecting data from Food Choice Lab
Generalize Let students select one of the following questions to answer: 1. http://www.bbc.com/earth/story/20160308-how-one-squirrel-manages-to-survive-being-frozen The arctic ground squirrel can tolerate having its body temperature drop below zero. Do any of our local animals have this ability? 2. https://www.chicagotribune.com/lifestyles/home/ct-garden-winter-freeze-morton-1220-20151214-story.html What "natural antifreeze" can can some plants provide to their cells?

Lesson 9

<table>
<tr><td colspan="2">Students will be able to calculate projected differences in population size with and without limiting factors.</td></tr>
<tr><td colspan="2">DCI
Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (LS2.A)</td></tr>
<tr><td>CCC
1. Patterns
2. Cause and Effect
5. Energy and Matter
7. Stability and Change</td><td>SEP
• Planning and Carrying Out Investigations
• Analyzing and Interpreting Data
• Using Mathematics and Computational Thinking
• Constructing Explanations and Designing Solutions
• Engaging in Argument from Evidence</td></tr>
<tr><td>Materials
• “Predicting Population Size” Worksheet</td><td>Safety Concerns
• Students need to have appropriate winter gear. Students should not be outside if the wind chill is below 13 degrees Fahrenheit.</td></tr>
<tr><td colspan="2">Opener Question
A “Limiting Factor” is anything that keeps a population from growing exponentially (growing faster and faster). Think of one thing that would keep a population of squirrels from multiplying and filling the school campus, write it on the sticky note provided, and place the note on the board.</td></tr>
<tr><td colspan="2">Access Prior Knowledge
Once all sticky notes are on the board, teacher works with the class to sort these factors into categories. (You may choose to lead to students to sort them into density-dependent and density independent factors OR into categories like disease, competition, predation, etc.).</td></tr>
<tr><td colspan="2">New Information
Teacher explains to students that they will be looking at survival rate data for a population of squirrels and drawing some conclusions about food availability and population size. (Note: Students will need to know how to write a claim based on evidence). Teacher explains that the graph on the worksheet is a from a study on squirrel populations in Ohio.</td></tr>
</table>

Apply
Students work through "Predicting Population Size Worksheet" in groups.

Afterwards, teacher leads a class discussion about findings. Some questions to pose to the class are…

- Why do you think squirrel survival rates are so low? (This is their evolved life history strategy)
- What did your graph of the population with access to UNLIMITED resources look like compared to your graph of LIMITED resources? (Unlimited resources - exponential growth, limited resources - logistic growth)
- Can you think of a real-life example of a population that is not restricted by limiting factors? (Bacteria in a Petri dish) Why are there so few examples of this?

Spend some time addressing whether or not the questions on the "Driving Question Board" were answered during the course of the past week. Ask students what questions they still have and let them know if you plan to address these questions in future units.

The remainder of the block can be spent completing Food Choice Lab. Students can compare data as a class by discussing their results in group. Then a spokesperson from the group can share the group's findings. Encourage students to discuss whether or not their hypotheses were supported by the data, and any possible sources of error.

Generalize
Exit Card: What limiting factors might restrict the growth of a population of milkweed plants?

Winter Environment and Ecology Assessment

Now that you have had the opportunity to learn from so many sources and experiments, it's time to teach younger students about the value and wonder of winter! You will have the opportunity to teach a small group (four to five kids) something about winter ecology or winter environment in a five-to-ten-minute outdoor lesson.

Before you begin, here are some questions to ask yourself:

- What did I learn about winter ecology or environment that I found the most interesting?
- What topic could I simplify enough so young students could understand it?
- How can I teach this topic in a way that gets the kids moving/thinking about the topic?

Your job:

Step 1: Write a rough draft mini-lesson plan (Use attached worksheet)

Step 2: Peer-edit by teaching your lesson to another group of students and recording feedback

Step 3: Change your lesson after reviewing feedback and present a final mini-lesson plan

Step 4: Teach the kids!

You will be graded according to the attached rubric. Please let your teacher know if you need any additional materials.

Need Inspiration? Check out:
http://www.earthrangers.org/wp-content/uploads/2016/05/enjoying_winter_with_your_class.pdf

Project Rubric

	Above and Beyond!	Acceptable	Needs Work
Timeliness	Both rough and final drafts were completed early enough that there was time for extra practice and editing.	Both rough and final drafts were completed on time.	Either one or both of the drafts were not completed on time.
Opener Question	Opener question helps students start thinking about the lesson topic and students provide responses to the question non-verbally (acting out, writing, demonstrating…)	Opener question helps students start thinking about the lesson topic.	Opener question does not relate to the topic of the lesson.
Lesson Accuracy	All information in the mini-lesson is accurate and is described in a way that the students can easily relate to.	All information in the mini-lesson is accurate.	Several ideas from the lesson plan are incorrect.
Student Interest	Lesson is fun and engaging. Students are moving around for most of the lesson.	Lesson is engaging. Students move for a minute or two during the lesson.	Students are not engaged and do not stand up during the lesson.
Review	Students are asked a question about the main idea of the lesson and have the opportunity to demonstrate whether or not they have learned the material.	Students are asked a question about the main idea of the lesson and have the chance to respond.	Student do not have the chance to respond to a question about the main idea of the lesson.

Mini-Lesson Plan (Rough Draft)

Name___________________

Goal - What do I want them to learn?

____

____

Opener question - What question will I ask them to get them thinking? How do I want them to respond?

____

____

____

New Information - What information will I teach them?

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Apply - How will they practice what they've learned?

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Review - What question will I ask to see if they've learned something? How do I want them to respond?

____

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Mini-Lesson Plan (Final Draft)

Name__________________

Goal - What do I want them to learn?

____

____

Opener question - What question will I ask them to get them thinking? How do I want them to respond?

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New Information - What information will I teach them?

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Apply - How will they practice what they've learned?

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Review - What question will I ask to see if they've learned something? How do I want them to respond?

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Food Choice Lab

Name_________________________

Hypothesis: If I provide local birds with ____________________ and ____________________ food choices, then the birds will prefer the ____________________ because________________ ____.

Dependent Variable: ____

Independent Variable: ____

Materials:

Procedure:

____

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Data:

Conclusion:

Insulative Qualities of Snow Lab

Name________________________

***Intro**: In this lab, you will have the opportunity to see if a dense snowpack or a loose snowpack provide better insulation for a "warm-blooded animal" (simulated by a beaker of warm water). It is up to you to decide how to test this hypothesis, so think about how you can set up an experiment to see which beaker will cool faster. Your teacher will provide you with warm water outside to pour into beakers.*

Hypothesis: If a warm object is placed under densely-packed snow, then it will cool faster/slower (circle one) than a similar object placed under loosely-packed snow.

Dependent Variable: ____

Independent Variable: Time (minutes)

Materials:

Procedure:

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Data (Include a sketch of your experimental set-up):

Table 1: Temperature Change Over Time

	0 min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)
Dense Snow Pack											
Loose Snow Pack											
Control											

Conclusion:

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Cytoplasm Concentration Lab

Name________________________

Intro: *Cells are filled with water, and water freezes, so what happens to all the important molecules dissolved in the cell if the water (cytoplasm) begins to freeze? If part of the water is frozen, what happens to the concentration of other materials in the water that is still liquid? We can simulate the process of a cell freezing by using food dye to represent the vital dissolved molecules in the cytoplasm. You can prepare two beakers: one one to place in the freezer (test beaker) and one to use as a control. Your teacher can place your test beaker in the freezer a couple hours before class starts so that some ice begins to form. When you remove this ice, how will the color intensity of the dye color compare to that of your control? What does this mean for plants and animals living in below-freezing temperatures?*

Hypothesis: If ice forms inside of the "cell" (cup), then the concentration of the cytoplasm would (increase/decrease/remain the same).

Dependent Variable: ____

Independent Variable: ____

Materials:

Procedure:

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Data (Draw a sketch of your two beakers after removing the ice from the test beaker):

Conclusion:

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Animal Insulators

Name________________________

Intro: *Similar to the "Insulative Qualities of Snow" Lab, you will be using beakers of warm water to simulate warm-blooded animals. This time, however, you will be able to test the effects of different insulators on animal temperature (such as feathers, fur, and fat) to see which is the most effective. You may choose to test the effect of the AMOUNT of insulator on temperature or the effect of the TYPE of insulator on temperature. In either case, how can you quantitatively measure the amount of insulator(s) you are using so that your results can be compared with the rest of the class? How can you set up an experimental control?*

Hypothesis: If two insulators are placed around beakers of warm water and placed in the snow, then the beaker surrounded by ____________________ will have a higher temperature than ____________________ after 20 minutes.

Dependent Variable: ____

Independent Variable: ____

Materials:

Procedure:

____

____

____

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____

Data:

Table 1: ____

	0 min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)	_____ min (℃)

Conclusion:

Reflectivity vs. Density Lab

Name________________________

***Intro**: In this lab , you will use a light meter to look for patterns between albedo (reflectivity) and snowpack density. First, decide how many areas you will sample. For each area selected, you will need to use the PVC pipe to measure snow density AND use the light meter to measure reflectivity. Use the table for data collection and create a graph to visualize results. What do your results mean in the context of climate change?*

Hypothesis: If the density and albedo of the snowpack are measured in various locations, then the density will increase/decrease (circle one) as albedo increases.

Dependent Variable: ____

Independent Variable: ____

Materials:

Procedure:

____

____

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____

Data:

Location #	1	2	3	4	5
Depth of Snow (cm)					
Radius of inside of pipe (cm)					
Volume of snow in pipe = πr^2(depth) (cm^3)					
Mass of Snow (g)					
Snowpack density (g/cm^3)					
Outgoing Illuminance (lux)					
Incoming Illuminance (lux)					
Albedo = Outgoing/Incoming (%)					

(Create a graph of results below)

Conclusion:

Rate of Photosynthesis Lab

Name________________________

Intro: *We know that chemical reactions typically occur more slowly in colder temperatures, but how is the rate of photosynthesis affected in the winter? Using the "Spinach Disk" Method explained by your teacher, how can you test how the rate of photosynthesis changes between warm and cold temperatures? There are many ways to test this hypothesis, so how will you run the experiment to get clear and accurate results?*

Hypothesis: If the rate of photosynthesis is compared between warm and cold temperatures, then photosynthesis will occur faster in warm/cold (circle one) temperatures.

Dependent Variable: ____

Independent Variable: ____

Materials:

Procedure:

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Data:

Conclusion:

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Torpor Chart

Name	**Body Mass (kg)**	**Min Temp (°C)**	**Average bout length (hours)**	**Sources**
Groundhog	3.4	5	364	Lyman (1958); Armitage et al. (2000); Zervanos et al. (2010)
House Mouse	0.037	16	5.9	Hudson and Scott (1979)
Eastern Chipmunk	0.087	4.9	120	Wang and Hudson (1971); Pivorun (1976); Levesque and Tattersall (2010)
American Black Bear	80	29.4		Watts et al. (1981); Tøien et al. (2011)
Big Brown Bat	0.015	1	488	Kulzer (1965) French (1985); Willis et al. (2005a)

Adapted from: Ruf, T., & Geiser, F. (2014).

Predicting Population Size

Name________________________

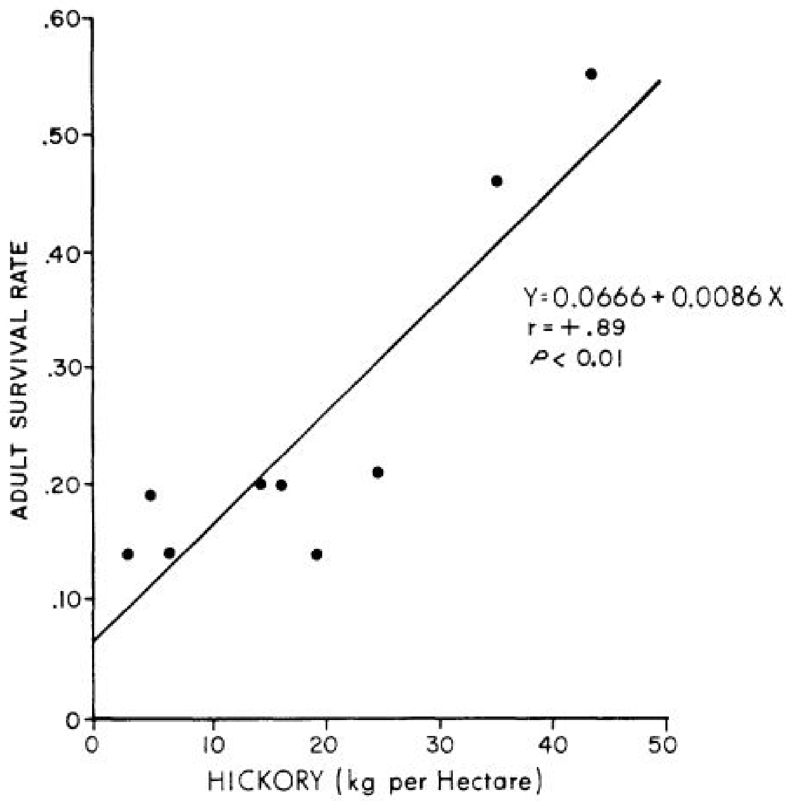


Fig. 3. The linear regression of the rate of survival of marked adult gray squirrels on the production of sound hickory seed at Waterloo, 1962–71.

Use the graph at the left to answer the following questions.

For all predictions, provide evidence from the graph and reasoning that ties your evidence back to your prediction.

1. According to the graph…
   a. Survival is dependent on food
   b. Food is dependent on survival
   c. Both variables are independent

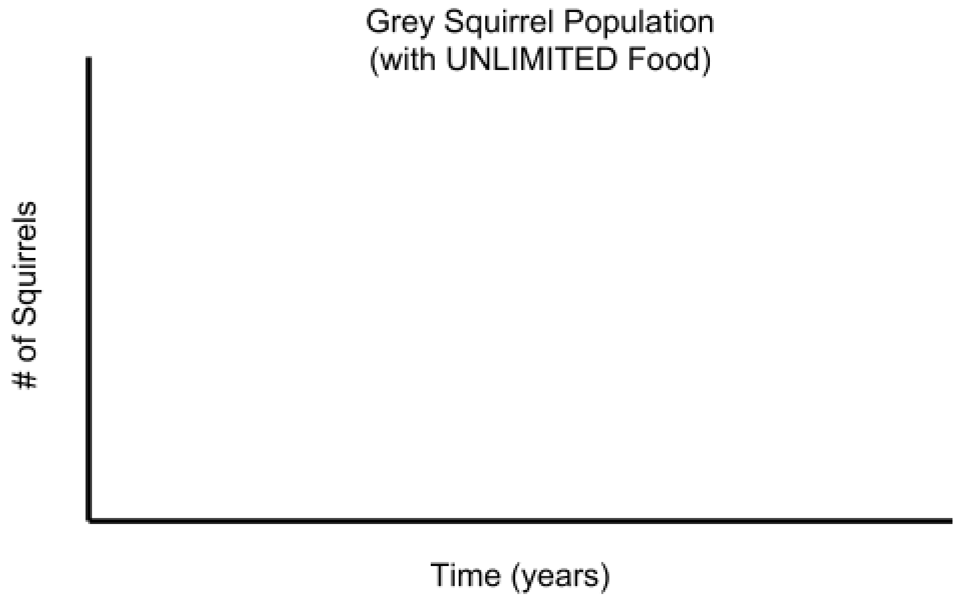
2. Imagine that a population of grey squirrels included 100 adults. If hickory production was 15 kg/ha in a certain year, how many of those adult squirrels would be expected to survive?
   a. 20
   b. 40
   c. 80

3. How many kilograms of hickory nuts would have to be produced (per hectare) in order for approximately 80% of the adult squirrels to survive?

4. Does the data show that food is a limiting factor for the squirrel population? Why or why not?

Graph from Nixon, C., McClain, M., & Donohoe, R. (1975). Effects of Hunting and Mast Crops on a Squirrel Population. The Journal of Wildlife Management, 39(1), 1-25. doi:10.2307/3800460

5. What would happen to the squirrel population if food resources were unlimited? Make a prediction on the graph to the right and provide evidence and reasoning for your claim.



Evidence:

Reasoning:

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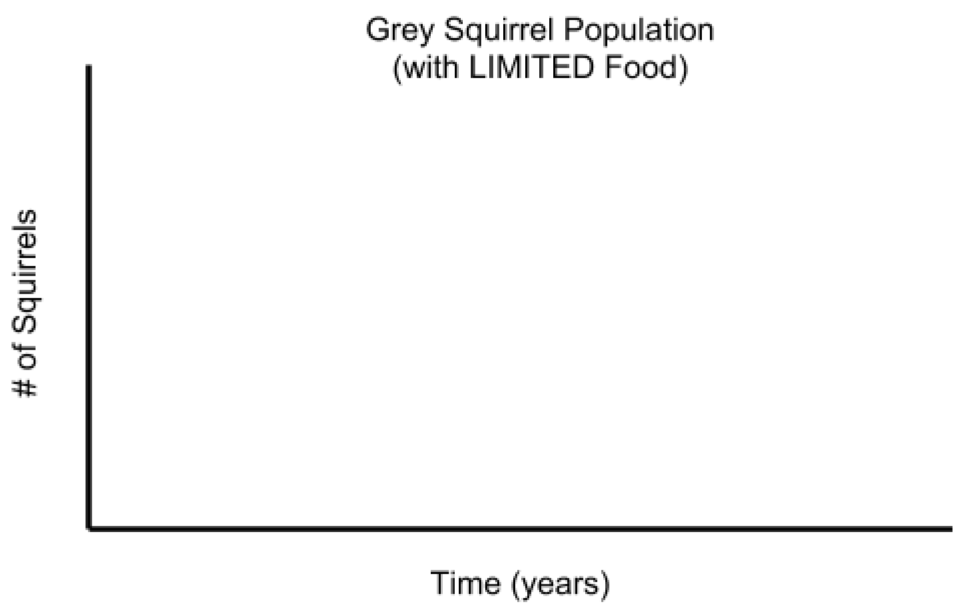
6. What would happen to the squirrel population if food resources (hickory nuts) were limited to 10 kg/ha/year for ten years straight? Make a prediction on the graph to the right and provide reasoning for your claim.



Evidence:

Reasoning:

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