Living with winter: An integrated curriculum for middle school grades

Kristine Lynn Buecking
The University of Montana

Follow this and additional works at: https://scholarworks.umt.edu/etd
Let us know how access to this document benefits you.

Recommended Citation

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.
Maureen and Mike
MANSFIELD LIBRARY

The University of MONTANA

Permission is granted by the author to reproduce this material in its entirety, provided that this material is used for scholarly purposes and is properly cited in published works and reports.

** Please check "Yes" or "No" and provide signature **

Yes, I grant permission
No, I do not grant permission

Author's Signature

Date March 16, 2000

Any copying for commercial purposes or financial gain may be undertaken only with the author's explicit consent.
LIVING WITH WINTER:
AN INTEGRATED CURRICULUM FOR MIDDLE SCHOOL GRADES.

by

Kristine Lynn Buecking

B.G.S. Simon Fraser University, 1991

presented in partial fulfillment of the requirements

for the degree of

Master of Science

The University of Montana

2000

Approved by:

[Signature]
Chairperson

[Signature]
Dean, Graduate School

3-16-2000

Date
Dedication and Acknowledgements

A giant thank you to my advisor and chief editor, Lisa Blank, whose knowledge of science education and trust in my ability to figure things out have been an inspiration; Elaine Caton for helpful advice on the written work and letting me tag along with winter ecology workshops for teachers; Chris Brick for teaching me about GLOBE and doing a preliminary review of the curriculum; Lisa Mills for giving the trunk a place to live and a purpose; Betty Roberge for finding the money and helping me put together the first annual Lubrecht winter festival.

The teachers who helped edit and provided valuable feedback to improve this curriculum deserve special thanks. Their guidance will ensure that other teachers will find Living With Winter to be a valuable resource for their classrooms. Of course, I can’t forget who this is all for: thanks to the students who tried out the lessons and who’s smiles and frowns gave me critical insights for improvements!

Special thanks to the following teachers for reviewing the lessons:

Ed Woyciechowicz-Lolo Elementary School

Nancy Typinski

Tara Barba-Target Range School

Melodee Smith-Burreson-Target Range School

Please do not copy any of these materials without prior permission. The Montana Natural History Center and the author depend on your financial support to continue to develop and run programs such as this. The rental agreement through MNHC entitles you to copy materials needed for lessons with your class. Any other reproduction of any kind can only be approved by the author.

For more information contact: Kris Buecking
406-327-7436 or k_buecking@hotmail.com
# Table of Contents

**Living With Winter: Teaching Manual**

- Why Study Winter? ................................................................. 4
- An Improved Approach to Environmental Education .................. 5
- Making Sense of Science: Conceptual Change Learning ............... 8
- How This Program Is Organized ................................................ 11
- Ongoing Activities ..................................................................... 13
- Introducing Winter To Your Students ....................................... 17

**Module One: What Is Winter?**

- Introduction ............................................................................... 18
- Lesson One: The What and Where of Winter .............................. 19
- Lesson Two: The Atmosphere and Wind .................................... 23
- Background Information for Enrichment: The Snow Factory ....... 28
- Lesson Three: What is Snow and How Does it Behave? ............... 29
- Lesson Four: Crystal Metamorphism Within the Snowpack ......... 32
- Background Information for Enrichment: Snow and Radiant Energy 39
- Lesson Five: Thermal Conductivity and Insulative Value of Snow .. 40

**Module Two: Animals in Winter**

- Introduction ............................................................................... 43
- Lesson One: Classifying Organisms Living With Winter .............. 44
- Lesson Two: Size Matters! .......................................................... 47
- Lesson Three: Fur-bearing Mammals and Winter ....................... 52
- Lesson Four: Winter Predator-Prey ........................................... 57
- Lesson Five: Animal Tracks ....................................................... 63

**Module Three: Humans and Winter**

- Introduction ............................................................................... 69
- Lesson One: Thermoregulation: Keeping Warm in Cold Places .... 70
- Lesson Two: Snow Shelters ....................................................... 75
- Lesson Three: Avalanche! .......................................................... 79
- Lesson Four: Cold-Related Injuries and Illnesses ....................... 84
- Lesson Five: Polar Expeditions .................................................. 91

**Appendix**

- Lesson Handouts ....................................................................... 93
- Trunk Materials ......................................................................... 105
- Letter to Parents ........................................................................ 106
- Web sites .................................................................................... 107
- References and Resources ......................................................... 108
LIVING WITH WINTER: TEACHING MANUAL

This manual is designed for middle school teachers (Grades 5-8) with an interest in supplementing their curriculum with an integrated study of winter-related topics. Science serves the foundation for many of the lessons. However, follow up activities and enrichment modules that explore a variety of subject areas are suggested. Teachers of either younger or older students could easily adapt these lessons to meet the needs of their students.

WHY STUDY WINTER?

An integrated curriculum for middle school which focuses on winter is unique. Few courses, or even texts, exist which explore this important topic that dramatically impacts life in northern climates and contributes to significant environmental issues. While individual teachers certainly incorporate some winter-related activities, no established program exists within schools in Missoula. Both Lubrecht Experimental Forest and Montana Natural History Center are seeking to develop their outreach programs for older students and have identified a need to offer more winter programming. Northwest Connections and Wild Rockies Field Institute offer winter ecology and field courses, but neither of these programs are designed for middle school students.

In addition to filling a gap in winter related content, this curriculum offers an element of novelty for students which all teachers recognize as an important component of meaningful and lasting educational experiences. Living With Winter addresses the criticism from students and teachers that the same topics and activities continue to be repeated in environmental education programs. Winter offers the potential for a fascinating study of the biological and physical processes in cold environments, as well as calling on students to extend themselves and realize their strengths and capabilities in dealing with adverse conditions. The extension of one's comfort zone, whether intellectual or physical, is a critical part of learning. Through actively engaging in the winter environment, exploring what is happening and why, and discovering how to be self-sufficient and comfortable in winter settings, learning is made relevant to students' everyday lives. Living with Winter answers the challenge of making science content, along with other curriculum areas, meaningful for learners.

A thematic, integrated approach to the curriculum will provide students with opportunities to think about complex relationships and systems, and establish a relevant context for all activities. Concepts such as snow metamorphosis, animal and plant adaptations to cold, insects and winter, and energy transfer can be examined through the inquiry-based, experiential activities offered in this curriculum guide.
Environmental education has been charged with the responsibility of reshaping the way that human beings think about ecological systems and, more importantly, how we behave and what we value. At its heart, this is about developing an "ethical view of the world and our obligations to it" (Orr, 1994, p.3). Environmental education is designed to help students learn about ecological concepts, environmental issues, interactions between humans and natural resources (Priest, 1990), and to become motivated to work towards solutions of environmental problems. The need to design and implement educational programs that impact how students think, feel, and act towards the environment, and create strong personal environmental ethics, has been recognized internationally. This curriculum package is designed to provide such a resource for classroom teachers.

Numerous formal and informal environmental education (EE) programs have been developed, implemented, and refined over the past few decades. While significant improvements have been made with respect to content and methods of EE courses, valid criticisms supported by research findings still exist and need to be addressed.

- **Inquiry Vs. Activity-Based:** Books and programs related to EE tend to provide teachers with a set of isolated activities to use in their classes that are designed to be fun and informative (e.g. Project Wild). Students walk away with some interesting facts that lack a relevant and meaningful context, "without knowing how to think in whole systems, how to find connections, how to ask big questions, and how to separate the trivial from the important" (Orr, p. 23). Educational research validates the need for inquiry and experiential learning that engage higher order thinking skills to affect cognitive development (Moscovici & Nelson, 1998). EE research indicates that programs that focus solely on increasing knowledge have little significant impact on students' attitudes and behaviors (Armstrong & Impara, 1991; Gudgeion & Thomson, 1991; Finger, 1994; Young & Horton, 1992). "In our attempt to make conservation easy, we have made it trivial" (Leopold, 1966).

**Lack of credibility and widespread applicability:** Numerous environmental and outdoor education programs currently exist in Montana and nearby States. However, few of these programs correlate the content of their courses with National Science Education Standards (NRC, 1996) or other curriculum standards. This failure is a significant obstacle to the credibility of EE as well as the integration and use of such programs in public schools as teachers are already overburdened with meeting various other curriculum objectives. The National Science Education Standards (NSES) serve to guide teachers and ensure consistency and accountability of curriculum. Currently, it is
the most appropriate set of standards available for EE programs. Some EE programs have begun to recognize the importance of correlating content with NSES, such as Project WET. This effort to align existing programs with national standards recognizes that EE programs need to continue moving in this direction.

- **Age-Appropriate and Coordinated vs. Overlapping and Repetitive Content:** EE programs have been criticized as lacking a coordinated effort and overall plan for the content and methods to be applied at each developmental stage of students (Weilbacher, 1995). This has resulted in repetition for students and confusion about sequencing programs to fit into a larger context for teachers. According to the Grand Unification Theory of EE (Weilbacher, 1995), which synthesizes feedback from recognized Outstanding Environmental Educators, middle school curriculum needs to integrate core sciences with issues, action, and outdoor education (p. 9) to be most effective. Programs need to address relevant topics, provide experiential opportunities, include community action projects, and tackle novel and often overlooked content areas and problem issues that are significant and meaningful environmental topics.

- **Local and Experiential vs. Global and Conceptual:** There is a fine line between encouraging students to ask big questions and looking at issues which are so global as to lose relevance to the student. EE programs have been criticized as overwhelming students with broad, abstract concepts and examining environmental problems which are so large as to leave one feeling doomed and helpless. In order for students to feel empowered to learn about issues and take action on problems, opportunities need to be provided that engage students in their local environment through direct experiences. Bioregionalism is a philosophy which promotes “living-in-place” through understanding the particular ecological relationships of an area, the social activities and behavior which have evolved and enrich life there, and “applying for membership in a biotic community and ceasing to be its exploiter” (Alexander, 1990, p. 163). “The crucial and perhaps only all-encompassing task is to understand place, the immediate specific place where we live” (Sale, 1985, p. 42). Curriculum, therefore, needs to deal with topics and issues that are relevant to where students' live.

- ** Appropriately Addressing Values and Ethics** Incorporation of values into curriculum is often associated with the process of indoctrinating students and, therefore, tends to be rejected within public education. Environmental education in particular has been associated with the imposition of particular values on students and thus makes many parents and educators uncomfortable. However, if environmental education is to affect not only students' ecological knowledge, but also their desire to work towards environmental solutions and sustainable lifestyle choices, then ethics must be incorporated in a way that challenges students to question what they believe and make thoughtful decisions that reflect well-informed values and ideas.
How Living With Winter Addresses EE Criticisms

Living With Winter incorporates interesting activities; however, each of these is set within a conceptual framework and engages higher order critical thinking skills that encourage students to ask big questions and explore a variety of answers. Through both classroom activities and outdoor experiences, students are challenged to stretch themselves, to step into unknown territories, and thus to draw meaning which is likely to have a significant impact on their lives. Each lesson outlines the NSES standards, or other curricular objectives which are effectively met. This ensures that teachers can use various modules, or the entire program, without falling behind in their overloaded schedules.

Living With Winter deals with an area of environmental curriculum that has been largely ignored and which is of significant importance in the lives of students in Missoula. In addition to learning winter ecology, students will be engaged in exploring such relevant topics as the conflict between winter recreationists and endangered wolverine populations. By incorporating core sciences with action projects and outdoor experiences, students will be engaged in learning about novel and relevant topics in ways that are age-appropriate.

This unit also incorporates a bioregional approach to environmental education in a variety of ways. First, the very topic itself, winter, is a vital force in shaping life in Missoula as well as other northern communities. Considering that approximately half of the school year is gripped by winter, it is appalling that there is such a dearth of information and curriculum aimed at broadening students' understanding and connection with this season. Second, to supplement other classroom work which focuses on more abstract concepts from textbooks, students will be learning through experiential activities that take place outside, in the school yard and surrounding areas. Students will be engaged with their local environment and the specific problems and issues associated with it. This scale, local rather than global, enables students to feel empowered instead of overwhelmed. Third, the focus on experiential education ensures that students who have not yet progressed from concrete to abstract ways of thinking, a common phenomena at early adolescence, will continue to be engaged. Missoula is an ideal place to incorporate winter ecology curriculum into schools given the high percentage of public land, the proximity to surrounding mountains and wilderness areas, and a long winter season. Winter is a critical component of living in this place, and this connection to where we live forms the foundation of developing a personal land ethic that can guide our behavior and lifestyle choices.

Living With Winter provides opportunities for students to gather information about different perspectives and think critically about complex issues, to reflect on what they believe, to clarify their own values, and to examine their behavior in relation to those values. This value-clarification process allows students to develop the thinking skills necessary to feel ownership and a genuine investment in their own beliefs and behavior. The goal is to facilitate the development of a personal environmental ethic within students that is not only informed by ecological knowledge, but also reflects a sense of fascination, wonder, and care for the natural world, and a desire and ability to act in ways that preserve ecological integrity.

Further Reading
Making Sense of Science: Conceptual Change Learning

You are a capable and experienced teacher and you've seen enough fads come and go to make you highly skeptical of the latest, greatest idea, which is what you've been doing forever with a fancier name. Phew!! Well, not to worry. You may or may not be familiar with this process of teaching science, but undoubtedly, it is worth reading this overview of the Conceptual Change model for learning science. Of course, you can call it whatever you want. What it all boils down to is finding ways to help students THINK like scientists. To do that, we need to move AWAY from the recipe-book experiments, the ways we learned science in school and are all too familiar with. We need to understand how scientists REALLY learn all of the incredible stuff that we now know about the world around us. We need to give kids the chance to mess around with ideas and concepts, to dive in and ponder and wonder and be confused and frustrated, and to come out the other end with newly formed impressions, identified assumptions, more complex thinking patterns. And, because of the reality we live in, we need to help administrators and parents understand that this IS education and it is VERY worthwhile. So what is Conceptual Change? Well...you might be doing it already!

Conceptual change is a model for teaching and learning that helps students understand patterns in the natural world, and to experience meaningful learning. Lessons flow from students' natural curiosity and interest about the subject being studied. The traditional 'recipe' style science classes, where students follow instructions towards pre-determined end results can lead students towards merely guessing the "right" answers. Here, an emphasis on formulating questions, making predictions, evaluating outcomes, and applying new learning engages higher order critical thinking skills. The past experiences and ideas which students bring to the class are the starting point. Through active lessons, these ideas are examined, clarified, and stretched. Students identify their own misconceptions and incorporate new information so that what they know is not only more accurate, but is remembered over a longer period of time. Thinking about the big ideas and discovering answers to important questions is the focus in conceptual change, rather than guessing what the teacher is thinking and manipulating findings to match specific, narrow results.

Conceptual change takes the best of what teachers have learned about hands-on instruction and incorporates scientific findings from cognitive research on how people gain understanding and knowledge. Instructional activities are designed which utilize both physical experiences (manipulation with objects, ideas, materials) and social interactions. As these activities incorporate what students already know about a topic, learners are able to construct understanding and apply it to real world problems. Students play an active role in their intellectual growth as they discover the discrepancies between their understandings of the world, then through guided experiences and discussion are able to construct meaning that is more aligned with what scientists know about the world.
Conceptual Change Instruction

There are four phases of the Conceptual Change model.

FOCUS

The first is the Focus phase which gives each student the opportunity to reflect on what they already know about a given concept. Journals can be used to guide students in What I Know/What I Think/What I Wonder types of brainstorms. Concept maps will help students clarify how they view relationships between the different parts of an idea. Having students predict outcomes of events through writing or drawing can reveal their own thinking about different processes. Students can also be interviewed answering specific questions to provide excellent documentation of their change in understanding before and after a conceptual change unit.

CHALLENGE

The second phase is called the challenge phase and the teacher helps create cognitive conflict for each student so that the discrepancies between their understandings and scientific explanations are realized. Using common, everyday experiences can be most effective in creating disequilibrium for students where they are forced to confront their own understanding or constructs in the face of discrepant information. Several challenge activities may be necessary to encourage students to fully uncover the holes in their own constructs.

CONCEPT INSTRUCTION

The third phase is the concept instruction phase and this is in which the teacher introduces scientific explanations about the concept being studied. A variety of exploratory activities are designed to help reinforce new understandings for students. The more experiences and discussions that engage students with a concept, the greater the opportunity for knowledge construction. Real world events and examples help make the ideas relevant for learners. Students are actively involved in integrating the new information and understanding by answering questions, performing experiments, making predictions, discussing ideas. Simply listening to a scientific explanation is not sufficient to help students broaden their understanding, though this can be included as one of the experiences.

APPLICATION

The final phase of the conceptual change model is the application phase. Here, the teacher presents a real-world problem associated with what students have been exploring. Students are encouraged to use the scientific point of view in creating a solution for the problem. Assumptions are challenged and students work together and with the teacher to reinforce the scientific understanding of the concept.

<table>
<thead>
<tr>
<th>What do students know about a topic?</th>
<th>Engage students in experiences that explore scientific explanations.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FOCUS</strong></td>
<td><strong>CHALLENGE</strong></td>
</tr>
<tr>
<td>How to create conflict in students' thinking?</td>
<td><strong>CONCEPT INSTRUCTION</strong></td>
</tr>
<tr>
<td></td>
<td>APPLICATION</td>
</tr>
<tr>
<td>What does all this mean in the real world?</td>
<td></td>
</tr>
</tbody>
</table>
The Role of the Teacher

The Conceptual Change model asks students to step outside of their comfort zone, to make themselves vulnerable by revealing their misconceptions and safely exploring ideas that are gradually incorporated into new understandings. The teacher is the facilitator not only of the intellectual part of this process, but also of establishing the emotional environment. Students need to feel safe in order to take the risks necessary to be effective conceptual change learners. The teacher's ability to ask challenging questions in the right way and at the right time, is paramount in creating an effective learning environment. Learning is an uncomfortable process and different students will express their discomfort differently. Teachers, by nature, are keen observers of student behavior and these skills will enable them to know when and how to push students so they stretch themselves, and when to back off.

Understanding what the hierarchy of process skills can help when facilitating discussions or designing activities to promote students' thinking about any given concept.

- Comparing—observing similarities and differences.
- Summarizing—to state briefly what the essence of something is.
- Observing—watching, perceiving, noticing something closely for a purpose.
- Classifying—putting objects or ideas into groups according to some principle.
- Interpreting—the process of putting meaning into or taking meaning out our experiences.
- Criticizing—making judgments, analyzing, making evaluations, looking at both the positive and negative aspects.
- Looking for Assumptions—examining the underlying thoughts, ideas that we take for granted, that are not based on factual support.
- Imagining—creatively picturing something that has not actually been experienced.
- Collecting and Organizing Data—either of the students' own choosing based on their interests, or from questions identified by the teacher.
- Hypothesizing—a suggestion about how something might work, a proposed explanation or solution to a problem.
- Applying Facts and Principles to New Situations—taking what students have learned and figuring out how it fits within a new context—rules, laws, principles, generalizations.
- Decision-Making—similar to the above situation, but the role of values is given more emphasis. What should be done and why?

The first five skills are expected for students to master at the early grade levels. The following skills, are standards which middle grade students are expected to achieve, particularly decision making. A variety of these process skills can be incorporated in each lesson, depending on the degree of challenge the teacher deems appropriate at any given time, for any particular student.

Living With Winter provides detailed background information for teachers as well as sample questions which can be used to challenge students' thinking. These questions are carefully framed to stimulate open-ended inquiry that taps into critical thinking skills, while avoiding leading questions that cause students to focus on guessing what the teacher wants
rather than constructing their own accurate understanding. Each lesson generally follows the conceptual change instructional model, although the exact terms at each stage are not used. Lessons start out asking students what they already know and encouraging them to articulate their current understandings clearly. Through inquiry activities, students are then presented with information and ideas that will challenge their thinking. Teachers' explanations and demonstrations follow the students exploring to enable each individual to construct new understandings. Finally, through evaluation and extension activities, teachers can provide students with opportunities to apply what they have learned to real-world situations and problems. Information is provided in the extension sections for teachers to develop their own activities for students who show a keen interest in any of those topics.

Further Reading
Jones, B.F.; A.S. Palincsar; D.S. Ogle; E.G. Carr (Editors). (1987) Strategic Teaching and Learning: Cognitive Instruction in the Content Areas. ASCD, North Central Regional Educational Laboratory; VA.

How This Program Is Organized
LIVING WITH WIVIL is organized into three main modules and two extension units. Each lesson within the modules is structured with the following headings:

Module Introduction This is a general overview of the unit. A list of further reading describes the sources of scientific information gathered for the various lessons and provides excellent resources for those teachers captivated by the subject and wanting to learn more.

Background Information Each lesson has an overview of scientific information which is designed to give the teacher a general understanding of the concepts being studied. Some of the broad concepts are defined and processes described. This section is not appropriate for reading directly to the students but can give the teacher enough of an understanding for the lessons to help direct students towards answering their own questions.

Big Ideas These specify the main ideas behind each lesson. When looking at each activity, referring back to the big idea should answer the question “so what?” and provide a rationale for undertaking the activity. Big ideas ground the lesson in something meaningful and provide the framework for the entire program. When parents arrive in your classroom and see a group of noisy, curious students messing about with various instruments of investigation, you can outline the big ideas and relieve their anxiety about the purpose of what they might view as random chaos.
**NSES Content/Curriculum Standards** These concepts are taken directly from the National Science Education Standards (NRC, 1996) and relate specifically to the lesson. Other curriculum standards which a lesson may pertain to are included, with the source cited directly afterwards. This enables teachers to keep track of the mandated objectives which they are appropriately meeting with the units they use from this program.

**Objectives**—These numbered statements are the specific, measurable outcomes for each lesson. They include the knowledge, attitudes, and skills which students are given the opportunity to gain through participation in the activities which follow.

**Materials** This section outlines the equipment and forms that are needed. Equipment such as videos, scientific supplies, etc. are included in the trunks which will be available either at Montana Natural History Center in their rental program, or at Lubrecht Experimental Forest classroom. Any materials that are not provided in the trunks are marked with an asterisk (*). These include the inexpensive, consumable items that are usually available and easy for teachers to gather. All of the task cards, instructions, and forms outlined are included with each lesson or in the appendix at the end of the guide.

**Time**—These are approximations for each section of the lesson that can be used as a guide for planning how to incorporate lessons into classroom schedules.

**Vocabulary** Related words that might not be familiar to either teachers or students, and which have not already been defined in the background information are included here.

**How the Lesson Works** The procedures for each lesson, presented in a step-by-step format for easy following. Where necessary, task cards and reproducible worksheets are also provided. Detailed descriptions for construction or other extension activities will be included in the appendix.

**Assessment** This section describes different ways that you can determine students understanding of each lesson. Most ideas presented are performance-based, and often assessment is integrated with the tasks for each activity. The science journal, with both directed reflection in addition to open writing time, provides an excellent tool for teachers’ to assess the level of student understanding. Where appropriate, sample rubrics are provided to structure journal assessment.

**Follow Up Ideas** Students and teachers who become keenly interested in the discussion that arises out of a particular lesson may refer to this section for ways of extending a lesson topic. These may also be used for homework assignments in some cases, or independent research projects. Feel free to substitute these ideas for the main lesson presented if the activity better suits the needs of the class.
Ongoing Activities

In order to maximize learning during each of these units, and to give students direct, ongoing experiences with the concepts being studied, consider establishing routines that include the following ongoing activities.

**MAKING DAILY WEATHER OBSERVATIONS**—Students can participate in visiting a government or industry managed weather station to learn about the real-world application of weather observations in a variety of fields including avalanche control, ski resort safety, highway and road clearing, scientific field stations. From there, they can return to the class and build a simplified version of a station which can be established in the school yard, with easy access from the classroom for making daily or weekly weather observations. For teachers interested in GLOBE, and how to collecting weather data that is used by scientists worldwide, contact: [www.globe.gov](http://www.globe.gov). In addition to gaining observation skills and an appreciation for weather patterns, they will also develop their ability to collect and record data, make and test predictions, and plot relevant information in graph form. Students can also check the internet for comparison of their own weather forecasts with national forecasts. The National Weather Service cite can be found at the following: [http://cnn.com/WEATHER/html/MissoulaMT.htm](http://cnn.com/WEATHER/html/MissoulaMT.htm).

- **SNOWFALL**
  Make two different snow measurement boards by cutting a 2X2 piece of plywood and attaching a yard or meter stick in the center.

  ![Diagram of snow measurement boards]

  **Total snowfall** One of these measurement boards can be used to determine overall snowfall throughout the winter and, therefore, should never be swept clean. At regular intervals, students can record the amount of snow on the board by looking at the yard stick. The snow will tend to slope upward against the yard stick, so have students draw an imaginary line across the top of the main snow platform to get a more accurate measurement. Differences between total precipitation and consolidated amounts can be
discussed.

**Storm board** The other measurement board can be used as a storm board and snowfall can be measured over different time periods. Students can sweep the base clean with a small broom before a predicted snow storm, then record the start and finish time, and determine the total snowfall for that period. If the time of each storm measurement is kept consistent (e.g. 24 hours) throughout the winter, then students can determine the maximum snowfall in a 24 hour period for the entire winter.

- **CLOUD COVER**
  By looking at the sky in an unobstructed location, students can subjectively determine the amount of cloud cover and record it using specific symbols.

<table>
<thead>
<tr>
<th>class</th>
<th>symbol</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td></td>
<td>No clouds</td>
</tr>
<tr>
<td>Partly cloudy</td>
<td></td>
<td>Clouds cover half or less of sky</td>
</tr>
<tr>
<td>Cloudy</td>
<td></td>
<td>Broken clouds; more than half but not all of the sky is covered</td>
</tr>
<tr>
<td>Overcast</td>
<td></td>
<td>Sky is completely covered</td>
</tr>
<tr>
<td>Obscured</td>
<td></td>
<td>Clouds are not discernable; mist or falling snow</td>
</tr>
</tbody>
</table>

- **AIR AND SURFACE TEMPERATURE**
  Students can build a Stevenson Screen (see instructions in appendix) to house the air temperature, or hang a thermometer one meter (yard) above the ground in the shade. They can use an old ski pole in the ground, or dig a wooden dowel with a nail on top to hang from. For surface temperature, a thermometer can be gently placed on the snow surface, away from any debris, direct sunlight, or large rocks or trees. For consistency over the winter, the thermometers need to be placed in the same location for every reading.

- **WIND DIRECTION AND STRENGTH**
  This is another observation skill that students will improve at with practice. The standard classification system is as follows:

<table>
<thead>
<tr>
<th>class</th>
<th>km/h</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calm</td>
<td>0</td>
<td>-No air in motion. Smoke rises vertically.</td>
</tr>
<tr>
<td>Light</td>
<td>1-25</td>
<td>-Light to gentle breeze, twigs in motion.</td>
</tr>
<tr>
<td>Moderate</td>
<td>26-40</td>
<td>-Fresh breeze; small trees sway. Snow begins to drift.</td>
</tr>
<tr>
<td>Strong</td>
<td>40+</td>
<td>-Strong breeze and gale; whole trees in motion; snow drifting.</td>
</tr>
</tbody>
</table>
**PRECIPITATION TYPE AND INTENSITY**

Precipitation in Missoula does not always arrive in the form of snow, therefore, it is useful to record the type of precipitation in terms of broader categories. Students can use their own judgment to determine which of the following precipitation types is occurring at the time of observation, and record this using the following symbols*:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Precipitation</td>
<td></td>
<td>NIL</td>
</tr>
<tr>
<td>Light Snow</td>
<td>Continuous fall that accumulates at a rate of 1cm per hour or less.</td>
<td>L</td>
</tr>
<tr>
<td>Moderate Snow</td>
<td>Snow accumulates at a rate of 1cm-3cm per hour.</td>
<td>M</td>
</tr>
<tr>
<td>Heavy Snow</td>
<td>Snow accumulates at a rate of more than 3cm per hour.</td>
<td>H</td>
</tr>
<tr>
<td>Very Light Rain</td>
<td>Less than 3mm of water per hour.</td>
<td>VLR</td>
</tr>
<tr>
<td>Light Rain</td>
<td>Accumulation of up to 3 mm of water per hour.</td>
<td>LR</td>
</tr>
<tr>
<td>Moderate Rain</td>
<td>Accumulation of 3mm to 8mm of water per hour.</td>
<td>MR</td>
</tr>
<tr>
<td>Heavy Rain</td>
<td>Accumulation of 8mm of water per hour or more.</td>
<td>HR</td>
</tr>
<tr>
<td>Freezing Rain</td>
<td></td>
<td>FR</td>
</tr>
<tr>
<td>Mixed Snow And Rain</td>
<td></td>
<td>SR</td>
</tr>
</tbody>
</table>

*This guide could be handed out to students, or you could have students brainstorm all the different precipitation types and decide on their own symbols to represent them. If they miss any that are listed here, you could add them to the students' list.
AVALANCHE FORECASTS
Students can use the internet to access regular avalanche forecasts, snow condition reports, and any avalanche accidents that occur throughout the winter. One great site for this is Cyberspace Snow and Avalanche Center (www.csac.org). A different student each month can be assigned the task of printing these bulletins and posting them somewhere in the class for everyone to check. Through regular monitoring from afar, students will be able to make predictions about what is happening in the snowpack before, during, and after they are making their own direct observations. Associating this with weather patterns is an excellent way to develop an understanding of the metamorphism processes that will be occurring within the snowpack and various elevations and slope angles.

* Students can construct a diagram of the evolving winter snowpack on chart paper (picture).

DAY LENGTH RECORDING
An interesting and important part of what defines winter is the actual length of day leading up to and after winter solstice (either December 21st or December 22nd). Starting in September, students can begin to record the length of daylight using the sunrise and sunset times given in the local newspaper. To do this online, contact: http://cnn.com/WEATHER/html/MissoulaMT.htm.

Using a daily log with times for sunrise, sunset, and the calculated length of daylight, students can gather enough data to develop graphs, and to begin to see patterns. For an extension of this, combine this information with daily temperature readings and try to determine whether there is a correlation between day length and temperature.
Introducing Winter
To Your Students

In order to engage students in the study of winter, you can choose from these starter activities which are designed to draw upon what students already know, to stimulate their questions and thinking, and to get them excited about investigating the natural world in winter.

• Individually, students can quietly brainstorm the following lists: what I know/what I think/what I wonder about winter. Then, in small groups, supply students with a large piece of paper and colored pens and have them share their ideas and generate a list that answers the question: "What is winter?" Each group can present their ideas to the rest of the class and one main chart of ideas can be developed which represents "Our Best Ideas So Far". Another chart can be generated which lists "What We Wonder about Winter". This is a critical component that will guide the teacher in choosing lessons that are relevant to what students want to know.

• Provide students with a map of the world and, in small groups, ask them to identify where winter occurs. After sharing ideas from this discussion, ask the students to come up with several hypotheses to answer the following questions:
  • Why does winter occur in these areas?
  • When does winter happen in different locations?
  • How is life (plants and animals) in these 'winter' areas different than in places which don't experience winter?
These discussions will stimulate students' thinking about various aspects of winter and will also provide the teacher with useful insights about the level of understanding which each student has and which concepts need to be challenged.

• Provide students with a journal and/or portfolio cover which will be used throughout the unit on winter. Students can cut/paste pictures from magazines as well as use their own drawings to create personalized collages on the cover of each of these which represent winter.

• Present students with a slideshow of winter related activities and phenomena. This can be done prior to a brainstorming activity (first in the list) or as a follow up.

• Take students on a snowshoe or cross-country ski walk-about. This can be guided by either having students make as many observations as they can about what winter is and how they would describe it, or after generating questions, they can focus on exploring the answer to one question during the hike. Stimulating students' ideas about the topic, then experiencing it directly is a powerful learning tool.
Module One: What is Winter

This module is designed to give students an opportunity to explore the basic concepts about why winter occurs, what criteria are used to define winter, and the specific properties and processes related to snow crystals and the snowpack. The first set of lessons focus on meteorological processes and energy:

- composition of the earth's atmosphere
- how wind is created
- how snow is produced
- how the earth's movement creates seasons
- solar radiation's effect on earth
- forms of energy and how energy is transferred.

The second set of lessons focus on what we most frequently associate with winter: snow. The lessons explore concepts such as:

- how snow crystals change in different weather conditions
- properties and characteristics of snow
- insulative qualities
- light penetration and reflection.

Further Reading

Lesson One: The What and Where of Winter

Background Information

What causes winter? This question intrigued anthropologists for many thousands of years. The myth that winter happens because the Earth is further away from the sun is still thought to be true by some people. In fact, during our winter, the Earth is closer to the sun than in summer (91,406,000 miles away as opposed to 93,500,000 miles!). It is strictly the tilt of the axis that entirely explains why we experience seasons. When the north pole is angled away from the sun, the solar radiation is spread out over a greater area, resulting in less radiation per given unit area. During the summer, it is more concentrated. This is why there are no seasons on or near to the equator. Here, there is little difference in solar radiation received at any given time during the year.

Human beings in northern climates perceive various qualities that they associate with winter: colder weather, less daylight, wind, less growth on plants, snow, ice formation, rain, cloudy days. These experiences are also associated with specific changes in behavior such as more time spent indoors, different recreational activities, and wearing different clothing. Scientists have determined that in different places around the world, there is an association between areas where humans perceive winter and distributions of winter adapted animal species (Halfpenny, 1989). Geographical areas where the influence of winter is significant enough to be a dominant evolutionary force, where populations (plants and animals) respond by developing specific adaptations, are defined as winter climates. Outside these areas, organisms may sense winter and make subtle changes in their behavior; however, these changes do not affect survival and reproduction enough to result in dramatic evolutionary adaptations. (These types of adaptations and processes will be explored in the Plants and Animals Module.)

So, what is winter, then? The scientific criteria of winter (Halfpenny 1998) are as follows:

- Mean January temperature of 30 degrees F (-1.1 degree C)
- Maximum expected wind speeds of 80 mph (37 m/s)
- Mean annual snowfall of 16 in (40cm)
- Mean annual insolation (incoming solar radiation) of about 375 cal/cm2 (this is lower than in summer)
- Continuous snow cover by Dec. 12
- Snow cover disappears after Feb 15

**MSEs Content Standards**

Earth in the Solar System:
The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of day.

**BIG IDEAS**

- The winter season is caused by the tilt of the Earth and the resulting variation in amount of solar radiation received at any point on the planet. Many of the environmental qualities which humans associate with winter are primarily a result of this change in insolation (Incoming SOLar radiATION).
OBJECTIVES

- Students will increase their understanding of how the tilt of the Earth's axis causes seasons in North America.
- Students will increase their understanding of how winter rays of sun transfer less energy to the Earth as a result of the lower angle, the larger area, and the longer path of radiation.
- Students will increase their understanding of how human beings perceive and define winter by identifying specific variables such as snowfall, accumulation and disappearance of snow, wind speeds, temperatures.

MATERIALS

- Chart paper and felt pens
- Task cards
- Exploration tubs
- Small lamp or flashlight
- Wooden stick
- Styrofoam ball
- Modeling clay
- Maps of North America which show: average date of continuous snow cover formation, average date of snow cover disappearance, mean annual snowfall, distribution of maximum expected wind speeds, mean January temperatures.

TIME

Introduction-30 minutes
Lesson-exploration 30 minutes, debrief 30 minutes, follow up (varies)

PROCEDURE

1. Introduction- Have students work in small groups of 2 or 3 to brainstorm a list of qualities which they associate with winter. Then have each group join one other group and, after reading each other's lists, have them work together to sort and categorize their ideas on a new chart. Each category of ideas needs a title. A representative from each group can present their classified list to the class. Similarities and differences between the student-generated lists can be discussed. (Optional: The entire class can work together to synthesize the various lists into one that everyone agrees on as the categories which define winter.)

2. Prepare tubs of exploration materials ahead of time and set out at various tables around the room. In new groups of 3-4 students, students can use the materials to answer the questions on the task cards.

3. Use the materials provided to discuss the following questions with your group:
   - How does the Earth move in space?
   - Why are there seasons?
   - What happens to cause winter?
   - Explain changes in length of days.
   - What information about winter do the maps tell you?

4. Signal to students to clean up work areas and to bring chairs and any materials, drawings, or models they need to explain to the class what they learned. First spend several minutes
their ideas. Do not correct 'wrong' answers, or ask leading questions that guide students towards guessing what you are thinking, but ask questions that encourage students to sort out contradictions between ideas, and present 'what about' type questions.

The following questions can be used to challenge students' thinking:

1. "Due to its elliptical orbit, the earth is closest to the sun in January, yet this is when northern areas experience winter. Explain how this works.

2. "If the earth receives the same amount of heat and light from the sun every day of the year, why are different amounts of solar radiation received at the earth's surface?

3. "How do the rays of sun in winter effect northern areas differently than in summer? Why are the effects different?

4. "What other influences or qualities of winter are not explained by these ideas?

Explanation: The slanted axis of the earth is the reason why we have seasons in areas away from the Equator. You can use a few simple tools to demonstrate this for students (Fig. 1):

- light bulb or flashlight, medium size styrofoam ball, knitting needle

Moving the ball around the "sun", students can see where the tilt of the earth in relation to the sun creates the different seasons within one year. Explain that one rotation on the axis represents one day, while one revolution around the sun represents one year. The tilt of the earth on the axis creates the change in how the sun's rays hit the earth. After this discussion, students can use their science journals to draw a diagram and write an explanation for why winter exists, including an explanation of how the earth rotates and orbits the sun, and the role the tilt of its axis plays.

To demonstrate how the sun's rays strike the Earth differently in winter, reducing the insolation per unit area, take a flashlight and hold it against a card that is perpendicular to the light (Fig. 2). Trace the outline of the rays on the card. Now, hold the card at an angle leaning away from the flashlight and trace the outline. This simulates how the tilt of the earth on its axis in winter causes a reduced angle of sun's rays and, therefore, less radiation received per unit area.

Looking at left side of each globe. 1 is summer, 2 is autumn, 3 is winter

Figure 1

* Adapted from Tik Liem's Invitations to Science Inquiry.
ASSESSMENT

• Each student can build a model which demonstrates and explains why winter occurs. Have them display these for other classes, and take the model to teach younger students this concept.

FOLLOW UP IDEAS

• In small groups, create a working model to demonstrate seasonal change, and the movement of earth in space. Have students teach this to younger grades.
• Have students investigate the weather records for their area: temperature lows, amount of snowfall, wind speeds, etc.
• Investigate current news that relates to winter weather events.
• Conduct long term weather observations throughout winter, using GLOBE or on your own.

CASE STUDY: Winter in Missoula-Temperature Inversions and Air Pollution

BACKGROUND INFORMATION:

Temperatures at higher elevations are successively colder. On a clear winter day the insolation is high, causing the earth to heat up. The earth’s surface emits longwave radiation but the net energy balance remains positive. When the sun sets, the insolation is reduced to zero while radiative loss remains high, creating a negative energy balance. As the ground becomes cooler, the air is slightly warmer and the warmer air transfers energy to the ground by conduction. The air continues to lose energy by this process and progressively cools from the base of the air column. Energy is transferred down the column to earth while the earth’s surface radiates energy to space, resulting in a temperature inversion. The longer the period of radiative cooling, the greater the development of the temperature inversion. Smoke and other pollutants cannot rise, because they want to travel from warmer to colder air. However, with an inversion, the warmer air is on top, thereby trapping the lighter air below the dense, cold layer. Temperature inversions are easily interrupted by wind; therefore, they are more common in valley bottoms during cold, clear and calm nights.

Encourage students to find newspaper articles from past issues of the Missoulian related to temperature inversion/air quality issue. A historical comparison to present day air quality will reveal a significant improvement. Students can develop a model or diagram which shows how temperature inversions are created and discuss the applications of this winter weather phenomena to air quality in Missoula.
Lesson Two: The Atmosphere and Wind

**BACKGROUND INFORMATION**

The earth's atmosphere is composed of a mixture of gases, with nitrogen and oxygen making up about 90% of the volume. Other constituents include argon, water vapor and carbon dioxide. Aerosols and solid and liquid particles such as dust and volcanic ash are important as condensation nuclei for precipitation. The proportional relationship of the atmosphere to the earth is analogous to the skin of an apple to the apple. The atmosphere is bound to the earth by the force of gravity; therefore, pressure is greatest at the surface of the earth, and decreases with altitude. Atmospheric pressure is measured in millibars (mb). Air pressure at sea level is 1013mb and at 18,000ft is 500mb. The density of the atmosphere varies due to the expansion and contraction of atmospheric gases during pressure changes at different elevations. The lower atmosphere, called the troposphere, is where most of our weather occurs.

The atmosphere is constantly moving and transporting heat, moisture, and momentum in the form of winds because of the transfer of heat from the ground to the air, and the evaporation and condensation of water. The earth's rotation on its axis adds to the complexity of circulation patterns. As air is heated it expands, causing the density to decrease. In order to establish equilibrium, warmer air, which is lighter than its surroundings, rises, while cooler air, which is more dense, sinks. Therefore, low level warm air will replace high level cold air. The temperature of a rising mass of air tends to decrease, which is why we often experience cooler temperatures at higher elevations.

Prevailing winds are the large scale systems of air flow found at 500mb. At this elevation, wind is relatively free from friction with the earth's surface, except where it passes over high mountain ranges. These systems are responsible for overall weather patterns, are usually well defined, and form the basis for long range meteorological predictions. Local wind systems, on the other hand, are significantly affected by friction from terrain features. As a result, these patterns are unpredictable and dependant on prevailing winds, terrain features, temperature, and time of day.

Understanding atmospheric processes and wind patterns is important to our study of winter because of their influences on weather patterns, responses of organisms to ensure survival, the creation of snow, snowpack characteristics, and how the snowpack is distributed across the landscape.

**NSSES CONTENT STANDARDS**

**Structure of the Earth System**
- The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.
- Global patterns of atmospheric movement influence local weather.

**Transfer of Energy**
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

**THE BIG IDEAS**
- The earth's atmosphere creates a downward force that is exerted due to the mass of air and earth's gravity and results in greater density near the earth's surface. Air density and pressure decrease with altitude.
- When air is compressed, its temperature rises, and when it is released, the molecules expand and cool. This warming and cooling (adiabatic processes) occurs whenever air is forced to travel upward or downward and have a significant affect on weather.
• Low level warm air tends to replace high level cold air, due to the differences in density and phenomena is a major force driving weather systems.

OBJECTIVES
• Students will develop an understanding that every substance has its own weight, including air.
• Students will gain an understanding of how the temperature of air increases with compression and decreases when it is released. Students will understand that air expands as it rises and when it is warmed.
• Students will gain an understanding of convection by seeing how a warm liquid rises through cooler surrounding liquid.
• Students will apply their findings about the behavior of air under differing conditions to make hypotheses about how the atmosphere works.

MATERIALS
Station One: Air Under Pressure-thermometer, bicycle pump, bicycle wheel and tire, paper and pens
Station Two: Air Expansion-large jar, cooking oil, tape, 1 yard plastic tube, paper and pens
Station Three: The Weight of Air-thin pole, balloons, scissors, string, tape, pin, paper and pens
Station Four: Convection of Hot and Cold Fluids-large jar, water, small cup, food coloring, rubber band, plastic wrap, stick, paper and pens

VOCABULARY
Troposphere—from the ground level to 11 miles above ground, lowest layer of the atmosphere. This is where most weather takes place. Temperatures decrease with height.
Stratosphere—from 11 miles to 31 miles above ground, with almost no weather activity. Temperatures increase with height.
Mesosphere—from 31 miles to 50 miles high. Temperatures decrease with height.
Thermosphere—from 50 miles to 310 miles above ground. Temperatures can exceed 3500 degrees F.
Exosphere—extends from 310 miles into space.
Adiabatic processes—the warming and cooling of air as it is compressed (temperature rises) and released (air expands and cools). These processes strongly affect weather and occur in the atmosphere whenever air is forced to travel upward or downward.

**Procedure**

This lesson may require 2 or 3 class periods, depending on whether you want students to have time at all the different stations. To introduce the topic, have students brainstorm individually in their science journals What I know/What I think/What I wonder about how the behavior of air influences the earth's atmosphere.

Students can rotate through the following stations, using the materials provided to explore the questions on the task cards.

**Station One: Air Under Pressure**

Use the materials provided to design an investigation of the following questions:

- How is air inside the tire tube different from air outside?
- How does the temperature of air differ under different degrees of pressure?
- When in nature is air forced to expand and contract? What happens with the temperature under these different conditions?
- Make some hypotheses about how this would influence weather. How could you test your hypotheses?

**Explanation:** Air can be compressed and when this happens, the temperature rises. If the pressure is released, and the air expands, the temperature will cool. This phenomena is called adiabatic warming and cooling. These processes have a large impact on weather! They occur in the atmosphere when air travels upwards or downwards, such as winds moving over mountain passes.

**Station Two: Air Expansion**

Fill the jar almost to the top with cooking oil. Tape the tube to the side of the jar after inserting it to within 1/4 inch from the bottom. Blow air bubbles into the tube and observe how they behave. Explore the following questions with your group:

- What happens to the size of the air bubbles?
- Make some hypotheses about why this is happening. How can you test these?
- What role does the oil play in this experiment?
- How does this relate to air rising in the atmosphere? What behaves like the oil to influence air?
- What does this mean in terms of weather? Draw a diagram to illustrate your ideas.

**Explanation:** As air rises, the distance to the ceiling of the atmosphere becomes less, so the mass of air pressing on it is reduced, giving it the chance to expand. This investigation shows this process visually as a bubble of air rises through a liquid medium. The bubble of air expands as it rises because there is less pressure on it the closer it gets to the top.
Station Three: The Weight of Air

Use the balloons as containers for air and design an investigation to determine whether air has weight. You can poke a hole through the balloon that releases air slowly if you first put a piece of tape on the surface of the balloon. Discuss the following questions with your group and write your answers on the paper provided.

- Does air have weight? How do you know?
- What other experiences have you had that might provide information about the properties of air?
- If we know that the atmosphere is 370 miles thick and is composed of gases that together we call air, what hypotheses can you make about properties of the atmosphere?
- What is air pressure? How might it change with altitude, if at all? How do you know?

Explanation: This investigation demonstrates that air, like all matter, has weight. The atmosphere is very thick (approximately 370 miles) and the weight of all that air creates pressure against the earth's surface. Those molecules are squeezed together more near the bottom than near the top of the layers of the atmosphere, making air density greatest at sea level. Another way of showing students this is by placing a ruler on a table, with 8 cm overhanging the edge. Ask them what will happen if you hit it and they will likely say it will flip up. Show them this. Then, place 2 full sheets of newspaper over the ruler and smooth it out with one hand and hit the ruler. The end will break off because of the atmospheric pressure exerted over the area of the newspaper. (For more details, see Tik Liem's book.)

Station Four: Convection of Hot and Cold Fluids

Fill a cup with colored hot water and securely cover it. Fill the jar with cold water and design an investigation which demonstrates how the different temperatures of the water interact with one another. Use food coloring so that you can see what is happening to the different temperature fluids. Before performing your experiment, make some predictions and write these on the paper provided. During your investigation, answer the following questions with your group:

- What do you observe happening with the warm and cold fluids?
- What happens to air when it is heated? How do warm and cold air interact with each other?
- What rules do you think that molecules behave according to? Write down three.
- How do warm and cold air interact in the atmosphere? What influence do you think this has on weather? How could you test this?

*Adapted from Reader's Digest "How The Weather Works"

Demonstration: After students have the chance to explore the different temperature fluids, perform the following demonstration for them (Fig. 3). Using four plastic pop bottles, fill two with warm water and two with cold water. Add food coloring to one of the
warm bottles (blue) and one of the cold bottles (red). Using a card to place between the two mouths, invert the clear warm bottle on top of the colored cold bottle and remove the card. Do the same thing with the clear cold water (top) and the colored warm water (bottom). Watch what happens.

![Diagram showing two pop bottles: one with blue-warm and red-cold, and another with red-warm and blue-cold. The result shows do not mix and mixed purple.]

**Figure 3** *Adapted from Tik Liem's Invitations to Science Inquiry.

**Explanation:** Warming a liquid or gas causes the molecules to move apart, becoming less dense. When mixed with cooler surroundings, the warm substance weighs less and so it will rise. As it cools, the molecules move closer together, the substance becomes more dense again, and it will sink. In the demonstration, students will see that in the second set of bottles (cold on top, warm on bottom), the liquids will mix because convection currents are created as the cold fluid sinks and the warm fluid rises. In the first set of pop bottles, no mixing will occur because the warm fluid stays on top (less dense) and the cold fluid stays on bottom (more dense).

**Debrief** Your debrief can loosely follow this outline, allowing different students to answer each question and paraphrasing or clarifying their responses.

- *What observations did you make at the different stations?*
- *What surprised you most about your findings?*
- *What new understandings have you gained about the behavior of air and what this means in terms of our atmosphere and weather systems?*

Once students have shared their general observations, you can challenge their thinking by asking them to resolve contradictions in their own ideas or between different students, and by presenting information which encourages them to construct more accurate explanations for their findings.

**Assessment**

Ask students to explain (with diagrams) the four phenomena explored at the stations using their science journals. Extension questions which encourage the application of what students have learned to new situations may include the following:

- *Explain why the air pressure is lower at the top of Everest than it is here?*
- *How does sun's energy influence the behavior of air?*
- *What causes wind?*
Describe how air movement in winter is different/similar compared to other seasons? Any or all of these questions may be explored in science journals. Encourage students to ask more of their own questions in their writing as well.

FOLLOW UP IDEAS

- Create an aneroid barometer to measure air pressure changes
- Research high altitude mountaineering. Describe how the conditions at the summit of Everest differ from those we find here. Why do these differences so dramatic?
- Design a model which illustrates atmospheric processes

The Snow Factory

BACKGROUND INFORMATION FOR ENRICHMENT

This lesson begins our exploration of the weather factor most commonly associated with the arrival of winter: snow. Specifically, we will investigate what happens at the atmospheric level to create the snow covered environment that we live in.

Moisture in the form of water vapor must be present in the atmosphere for snow to fall. In Western mountains, this comes from the Pacific ocean. Moist air moves inland from this body of water due to the low pressure which develops over the Gulf of Alaska in winter. Heavy snowfalls in the Pacific Northwest are the result. Warm moist air from the Gulf of Mexico meeting cold arctic air often results in heavy snowfall on the eastern slopes of the Rocky mountains. Ranges close to the ocean receive unpredictable, heavy snow, with variable temperatures, whereas, inland conditions are more predictable, with lighter and drier snowfalls. There are three ways in which molecules in water vapor rise and produce snow: orographic lifting, cyclonic lifting, and frontal lifting.

Orographic lifting is the most important mechanism in the production of severe storms in the western mountains. As horizontally moving air masses are forced over mountain ranges, they rise and cool rapidly. This rate of lifting is ten times greater than either cyclonic or frontal. The amount of precipitation which results depends on the moisture in the air and the rate of lifting. The rate of lifting, in turn, depends on wind speed, slope of the mountain, and how close to a right angle the wind hits the barrier.

Cyclonic lifting is a product of the general circulation pattern of the atmosphere. These circulating air masses are the result of low pressure and can range in diameter. In the northern hemisphere, air circulates counter-clockwise. In the absence of mountains, the rate of lifting is typically steady and weather will be uniformly cloudy with moderate precipitation. Mountains act as a modifying influence on cyclonic lifting, changing precipitation patterns.

Frontal lifting refers to the various influences that weather fronts, the boundary where air masses meet, have on one another. Masses of air circulating around an area of low pressure often have come from different geographic areas and sharp transition zones sometimes result. Cold air is more dense than warm air, therefore, the warm air will typically ride up over the cold air causing lifting which results in precipitation.

The warmer the air, the more moisture it can carry, so storms that originate from warmer areas typically generate greater snowfall. The faster air rises, the greater the intensity of snowfall. Maximum snowfall occurs when a mountain range is at right angles to the moisture-carrying winds. The deposition of snow on mountain ranges depends on whether they confront major weather systems or smaller local wind patterns. As moist air rises, it cools due to the expansion of molecules (decreased pressure) and decrease in temperature with altitude. Cooler air cannot hold as much moisture, so condensation occurs. If the temperature where condensation occurs is below freezing, the snow results. Crystals form when water vapor freezes around a nucleating agent. The crystal type is determined by the temperature and available vapor supply during formation. The maximum precipitation occurs at the base of clouds where there is maximum moisture and maximum condensation. Precipitation continues until all the moisture is used up, or the moist air stops rising and passes over the mountain range.
Lesson Three: What Is Snow and How Does It Behave

BACKGROUND INFORMATION

The previous lesson and background information explored how snow is formed in the atmosphere, and the associated weather systems. This lesson examines snow as it is falling, and its properties once it collects on the earth's surface to form a snowpack.

Snow plays a significant role in the ecology of northern climates. The Inuit and northern Indian people, who live with snow almost year round, have developed a large vocabulary of words to describe the intricate differences and subtle variations found in different types of snow. Snow crystals grow when water vapor from the air is transferred and freezes. The type of crystal formed is dependant on the temperature and the available vapor supply. Falling snow is classified by crystal type according to the International Snow Classification System and can be one of several different types. Use the crystal cards provided in the trunk to help identify the following types:

- **Columns** are hollow needles
- **Needles** are solid crystals
- **Spatial dendrites** are three-dimensional crystals
- **Plates**
- **Stellar crystals** which is the six-sided form we typically associated with a snowflake
- **Graupel** is formed by extensive rimming (supercooled droplets of water collide with the crystal and freeze to it)

Collectively, specific properties of snow can be observed and measured. The density of snow can be measured, usually in terms of grams per cubic centimeter. The density of snow indicates the amount of water it contains. The snowpack on the ground consists of only a small proportion of water and is, in fact, mostly air. The age of snow can be estimated according to the amount of metamorphism that has occurred or roughly by its density. Generally, density increases with time on the ground, with the exception of depth hoar formation. This is where crystals separate and grow into large, angular forms, and have the consistency of sugar. (See lesson on Crystal Metamorphism!) Snow has plasticity, that is the ability to move and deform without breaking. It can flow around objects and create a hollow cavity next to an object which provides an area where rodents and insects may travel easily. Snow has a low thermal conductivity and therefore makes a good insulator (see Lesson Nine). The hardness of different layers, surface roughness, strength, reflectivity and absorption of light of a snowpack can also be measured.

THE BIG IDEAS

- Snow is a form of matter and as such has specific properties which can be observed and measured. These properties vary widely depending on environmental conditions.
- These properties contribute to snow behaving in certain characteristic ways that have consequences for living things.

NSF CONCEPT STANDARDS

Properties and Changes in Properties of Matter

- A substance has characteristic properties, such as density.

Structure of the Earth System

- Water circulates through the crust, oceans, and atmosphere in what is known as the "water cycle". Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface.

NSF GUIDELINES

Changes in Matter

Learners understand the properties of the substances that make up objects or materials found in the environment.

- Explain an object's characteristics based on its composition and how it was formed.
- Explain the different phases of matter in terms of atomic and molecular motion.

Learners are able to synthesize their observations and findings into coherent explanations.
OBJECTIVES

- Students will gain an understanding of the different properties of snow.
- Students will gain observation and measurement skills and will interpret data.

PROCEDURE

Part One: Classroom Explorations

This lesson allows students to examine indirect information and their own experiences to make inferences about some of the properties and characteristics of snow. Students can use their science journals to record their findings.

1. Students can write down the properties of snow based on their personal experiences in snowy environments, using the worksheet provided.

2. Provide students with several photographs (You could have students take their own photographs 2 weeks before you plan to teach this lesson) of snow. For example, hanging from a roof, mushroomed on top of a stump, in trees, on the ground, blowing, cornices on ridge tops, etc. Students can examine these photos to add to their list of inferred properties.

Part Two: Field-based Experiments

Have students choose three different outdoor sites to make the following measurements and observations (Use the GLOBE protocols if you want!)

- Snowpack depth
- Density (use can with both ends open, crystal screen, and spring scale)

Also ask students to make as many observations as they can about the characteristics of snow as they walk around. This exercise can be conducted over a longer period of time, with several observations being made throughout the winter. Use the magnifying glasses and crystal cards provided to help with close-up observations.

Explanation: The following properties are associated with snow (Halfpenny 1998):

DENSITY - Snow can be measured in terms of water content (how much water it contains), and this water content will have a specific density. The density will vary and the characteristics of snow differ somewhat with different densities. Most researchers measure this in terms of grams per cubic centimeter. If you take a cup of snow and melt it,
you can get a quick visual display of its water content. Have students predict this for different types of snow.

**AGE**—As snow has been sitting around on the ground throughout the winter, it ages and its feel, look, shape, density, and other characteristics will change as a result. Density tends to increase with time on the ground. Students can melt cups of different age snow to see the change in water content.

**PLASTICITY**—Snow tends to behave like water but in very slow motion. It can move and deform without breaking. Seeing clumps of snow hanging from roof tops, or mushrooming on tree stumps is a great visual display of this. This is important for animals living under the snow, as it leaves spaces for them to move around in.

**THERMAL CONDUCTIVITY**—This is the rate of heat (energy) moving through the snowpack. Snow has a low rate of movement (or thermal conductivity), therefore it makes a good insulator. This is a very important property as we’ll see in the animal module.

**REFLECTANCE**—Also referred to as albedo, this is the amount of reflectance of shortwave radiation from the sun. We’ve probably all experienced this when squinting walking across the snow on a sunny day! Different things affect the albedo of the snow, such as sun angle, grain size, and surface conditions.

**ASSESSMENT**

- Through discussion with students, several of these ideas will likely emerge. Ask students to describe the main properties of snow in their own words in their science journals, and draw diagrams. You can introduce the terms associated with these properties after this.
- Students can draw posters to illustrate the main properties of snow. Ask them to include another example of a different substance that also demonstrates each property.

**FOLLOW UP IDEAS**

- Ask the students to keep an ongoing sketch book or photograph collection of snow in all its various forms.
- Students can develop a secret language with 20 different vocabulary words to describe different conditions of snow. (Later they can compare this to Inuit vocabulary for snow!)
Lesson Four: Crystal Metamorphism Within The Snowpack

**BACKGROUND INFORMATION**

Snowpack layers are a graphic history of winter weather. By understanding the processes that affect the layers of snow on the ground, and being able to identify the factors which led to each process, students can keep an accurate record of the weather patterns for the entire winter. Once snow has fallen in layers on the ground, the action of three different processes is likely to affect the crystals collectively. Each of these processes is influenced by time, internal snowpack characteristics, and external weather conditions. The resulting crystal formations have implications for how the snowpack looks and behaves, what that means for animals living in the subnivean environment (beneath the surface of snow), as well as, the degree of avalanche hazard across a slope. These processes are destructive metamorphism, constructive metamorphism, and melt metamorphism.

**Destructive metamorphism** (EQUI-TEMPERATURE SNOW-ET) occurs when the air temperature is relatively warm and when there is an equal temperature distribution within the snowpack. The initial deterioration of the snowflake due to mechanical damage, either from falling or the impact and weight of other snow crystals, results in rounded ice grains in the snowpack. The surface of each snowflake has its water molecules reordered resulting in a loss of fine structure. The spherical particle ends up with a net reduction in surface area. These individual grains come together, with the smaller being reabsorbed by the larger ones, until all of them are roughly the same size (Fig. 4) Wind packing and the weight of overlying snow also influence this process. As snowpack airspaces are reduced in size, individual grains bond at points of contact, causing the overall mechanical strength and density of the snowpack to increase substantially. This can occur within a few hours after snowfall under the right conditions. This process is what allows snow shelters, such as igloos and quinzees to work. Stomping on the snow mimics destructive metamorphism, causing a strengthening of the bonds between crystals and the formation of chunks or blocks which can be cut and used for shelter.

**Summary: Roundps (ET snow)**

**Conditions**
- lacks significant temperature gradient
- cloudy, warm
- thick snowpack
Figure 4

**Constructive metamorphism** (TEMPERATURE GRADIENT SNOW-TG) occurs after initial snowfall and destructive metamorphism, due to the change in vertical structure of the snowpack. This process results from the migration of water vapor up through the snowpack when both a temperature gradient exists from the bottom to the top, and when an interconnected system of pores within the snowpack is present. The temperature gradient usually exists because of the low thermal conductivity of snow. When the air temperature is cold, the upper layers of snow are affected, while the lower layers are influenced by the constant heat from the ground. Air spaces within the snowpack remain saturated (100% humidity) because of the continual process of sublimation. Sublimation happens when a substance changes from solid to vapor and back again, without passing through the liquid phase. Water molecules escaping from ice surfaces either end up returning to the ice surface or escaping due to their random movement. The amount of vapor in suspension at any given time increases with temperature, therefore, warmer regions (lower) will have a higher concentration of water vapor molecules for given volume of pore space than colder portions (upper). If a temperature gradient exists, then a vapor concentration gradient is also present. Due to the fact that molecules in suspension are continually bumping into each other and always trying to escape their confines, water vapor will tend to diffuse from areas of higher to areas of lower concentration, and from warmer to colder (see Convection station in Lesson Two). The upward migration of water vapor through the snowpack means two things:

1. Condensation occurs in the upper snowpack because the internal atmosphere is already at 100% relative humidity; therefore, the addition of more water vapor can only supersaturate the air. Condensation onto outside of ice grains results in growth of grains (Fig. 5).
2. Water vapor migrating upward is continually replaced in the lower regions as sublimation from ice crystals maintains a saturated atmosphere there. Therefore, ice crystals at the bottom of the pack are continually diminishing in size.

The end result of constructive metamorphisism is the formation of depth hoar-brittle, loosely arranged cup-like crystals. This sugary layer facilitates the movement of small mammals as they forage under the snow. The reduction in mechanical strength of the snowpack, however, leads to an increase in avalanche danger.

**Summary: Facets (TG snow)**

**Conditions**
- significant temperature gradient
- shallow snowpack, cold weather
- on shadowed aspects, near rocks or trees
- lower density, more porous snow

Figure 5
Melt metamorphism occurs when any part of the snowpack is exposed to temperatures above freezing. Water percolating through the snowpack (surface melt, rain, fog condensing) encounters lower temperatures and freezes. The meltwater acts as a heat pump gaining heat at the surface when changing from solid to liquid and transferring energy to lower layers of the snowpack when it freezes again. This process brings the whole snowpack rapidly to an equal temperature. The amount of heat released with rainfall depends on the temperature of rain and the quantity. With fog, the latent heat released when water condenses over cold snow to form the fog droplet is high. For every gram of water vapor condensed on the snow surface, enough heat energy is released to melt seven times as much ice. This is why snow disappears much more quickly in fog than in rain.

Summary: Melt-Freeze

Conditions
- melting/freezing temperatures
- rain or warm weather

Figure 6

THE BIG IDEAS
- The layers of a snowpack present a graphic history of the winter's weather. Various environmental conditions lead to different processes within the snowpack, and these can be identified through observations of individual crystals within each layer.
- Different processes of metamorphism within the snowpack result in different qualities of strength which have both negative and positive consequences for animals and humans.

NSSE CONTENT STANDARDS
Properties and Changes of Properties in Matter
- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.

Transfer of Energy
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.
- Heat, light, mechanical motion, or electricity might all be involved in transferring energy into or out of a system.

EE GUIDELINES
Collecting information
- Learners are able to collect information about the environment in a variety of ways.
  - Observe systematically, measure accurately, keep thorough and accurate records.
  - Understand and can use various systems of measurement and derived measurements.
  - Collect firsthand information using field study skills.

Questioning
- Learners modify, clarify, and focus questions to guide their learning and environmental investigations.
OBJECTIVES
• Students will gain skills in making weather observations on a regular basis, including recording accumulated snowfall.
• Students will learn how to identify crystal types, and to record them using standardized symbols.
• Students will learn how to dig a snowpit, observe and identify layers within a snowpack, identify crystal types, measure snow and air temperatures, and record snowpit observations using a systematic procedure.
• Students will use snowpit observations as a basis for developing hypotheses about winter weather and how different factors affected the snow crystals, including which processes of metamorphism have occurred.
• Students will gain an appreciation for the complexity of snow crystal formation and metamorphism.

TIME
Introduction in class: 30 minutes
Snowpit digging and observing: 1-1/2 hours
Discussion-30 minutes

VOCABULARY
Sublimation-the conversion of ice directly to water vapor
Subnivean-refers to the environment below the snow
Latent heat-the energy gained or lost during phase changes in water
Depth hoar-recrystallized, sugary snow found in bottom layers of snowpack after period of very cold weather.

PROCEDURE

Part One: Classroom Introduction:
Identifying Crystals
1. Provide each student with a set of crystal photographs and have them examine each one carefully and write as many observations as possible on the back of each card.
2. Once students have completed this, have them partner up and discuss similarities and differences between the crystals.
3. Hand out symbol cards and ask each pair of students to try to match the symbol with the photograph. Each pair can present one match they decided upon to the class, providing an explanation for the pairing.
4. The teacher can then go through each crystal, describe any characteristics which the students may have missed, provide students with the name of each crystal type, and students can take notes, ask questions, etc.

MATERIALS
Snow crystal cards and magnifying glasses (one per pair of students)
Snow shovels
Outdoor clothing and footwear for working in snow
Winter gloves
Thermometers (one each)
Probe or ski pole
Snowpit observation chart and pencils
Photographs or drawings of snow crystals and cards with crystal symbol and name
Rulers
Crystal Metamorphism poster
Part Two: Digging Snowpits in the Field

Preparation: Ensure that students are properly dressed for spending time in the snow. They will be writing observations and working with their hands, so warm winter gloves will be essential.

Once students arrive in the area where pits will be dug, the teacher can dig a demonstration pit using the following guidelines:

- Probe area to ensure that there isn't a large stump or small tree that will be in the way.
- Mark out area (approximately 2 square yards) and sketch on surface of snow so that no one walks across the top. Ensure that the pit wall is perpendicular to the slope and that the sun will not be directly hitting the wall where you will be making your observations.
- Have 2 students help you remove enough snow to enable you to stand on ground against wall of pit, while students are still able to gather around to see.
- Using shovel blade, then back of gloved hand, try to smooth out wall of pit as much as possible. Encourage students to begin making observations about the various layers that emerge as you are "brushing" the wall.
- Using crystal card, draw lines along obvious layers, have students recall weather patterns and predict what might have been happening to form those particular layers.
- Cut out small shelf to keep observation equipment, set up ruler in corner of pit, start recording observations. You may wish to have students observe the entire process, or, after observing how pit is dug, go dig their own (in partners) and make their own observations.
- Once pit is dug, current weather, depth of snowpack, height of obvious layers, temperature profile, and crystal identification within each layer can be recorded.

If there is time, each pair of students can observe one or two other pits and discuss similarities and differences with other students. This can happen either in the field or when you return to class. Questions you can pose may include:

- Why are there differences between people's snowpit observations? (human error, differing interpretations, different slope aspects, effect of solar radiation on someone's wall, proximity to tree, rock, etc. which will effect crystal metamorphism, etc.) Should all of the snowpit profiles be identical?
- What similarities did people find? (probably obvious layers, more than crystal types)
- How was the process of identifying crystals? Did anything make it easier/harder?

Upon returning to the classroom, have students post their observation charts and walk around to make comparisons and ask each other questions about their findings.
**ASSESSMENT**

Once students have observed and discussed differences between snowpit observations and possible reasons why, have them complete a self evaluation regarding their skills in digging the snowpit, ability to make observations, and possible areas for improvement. You can also develop questions which encourage students to make hypotheses, develop predictions, and to apply their understanding to new situations.

**SAMPLE QUESTIONS**

What were your most significant learnings from this lesson?
What skills do you need more practice with? Why?
What presented the biggest challenges for you? What could you do to improve in those areas?
List the major layers that you found in your analysis and describe what conditions/factors/events you think may have caused those layers to be present.
If the next 2 weeks was very cold with little to no wind, make some predictions about what you would find in your next snowpit. Describe and/or draw your conclusions.

**FOLLOW UP IDEAS**

This lesson is most effective if students have the opportunity to dig a snowpit and record their observations at least three times throughout the winter: beginning, middle, and end. Further, understanding the processes which are going on in the snowpack throughout the winter will be easier if students have the opportunity to make regular weather observations and predictions about layers developing and being transformed.

- Students can use the internet to access the Cyberspace Snow and Avalanche Center to print out weather and snowpit observations from around the country.
- Students can visit a weather observations site that is maintained by industry or government technicians, or a local ski hill to witness observations being made.
Snowpack Observations

Date ____________________
Location ____________________

Air Temperature__________ Surface Temperature __________

Predictions about general characteristics of snowpack (Temperature Gradient or Equitemperature-why? what do you expect to observe?)


Initial observations (moisture content, evidence of wind, recent weather)
Surface condition


Snow loading (presence on trees? rocks? piled up in places?)


Foot penetration


Other observations


Digging A Pit
What do you notice while digging?

Layering (identify each major layer, crystal type, approximate depth, temperature)


Stepping Back
How did your predictions match with your observations?


Surprises?
Fresh snow is nature's best reflector, turning back 75-95% of sunlight striking the surface. The solar energy that is reflected is either lost back into space or absorbed by objects above the snowpack. The result is little energy left to perform work, that is raise the temperature, in the snowpack. As the snowpack ages, it accumulates dirt, leaves, and other objects on the surface and the reflectance may decrease to as little as 45%. Snow is a reflector of short wave radiation and an absorber of long wave radiation, the same type of heat energy emitted by terrestrial objects. Physicists refer to "black bodies" as objects that absorb 100% of the energy incident upon it, and nothing in nature approximates this with longwave lengths as closely as a snowpack.

All objects emit some heat energy from molecular activity. The snowpack is continually absorbing energy from its surroundings, like trees and rocks. This is why you will tend to see depressions around things like trees and rocks. (These depressions are created more by sublimation-change of substance from solid to vapor, without turning into liquid- than by actual melting of snow.) In addition, the snowpack efficiently emits or radiates energy back to its surroundings. The lowest temperatures in any winter environment are usually at night right at the snow's surface due to the loss of insolation and the continuation of radiation. Temperature inversions can occur during cold, clear weather provided no overhead obstruction is present to absorb outgoing radiation and re-radiate it back to the snow. In a small forest clearing where surrounding trees are taller than the diameter of the clearing, snowmelt is often delayed. This is due to the unimpeded loss of heat energy from the snow surface to space, with the surrounding trees intercepting incoming solar radiation, creating a negative energy balance. The increased deposition of snow in forest clearings also contributes to later lying snowpacks.

When you compare snow to ice, the generalization is often made that the transparency of snow, that is the ability for light to pass through, increases as density increases to that approaching ice. This generalization, however, does not hold true. Imagine, for example, the difference between a snowball and a handful of loose snow held up to the light. In this case, loose snow is less dense, yet will be more transparent. The behavior of light in snow depends on the degree to which the snowpack has been altered by metamorphic processes. For our purposes, we will be looking at seasonal snowpacks of relatively low density and ignore the situation of highly metamorphosed permanent snowfields that is found in arctic and alpine regions.

The accumulation and settling of fresh snow is accompanied by a marked decrease in light transmission. An increase in density of .05g/cm³ in a surface layer would have approximately the same effect as the addition of 10 cm of new snow, and reduces the amount of light passing through by 50% at any given depth (Holfpenny & Ozanne, 1989). The critical density of snow is .5g/cm³ and this is where maximum absorption of light and minimum transmission occurs.

Every time a light beam passes through and out of an ice grain, it's direction is changed by refraction. The bending of the light beam occurs at the ice/air interface, therefore greater surface area of ice grains in a given volume of snow means a greater amount of internal light scattering caused by refraction and the greater the absorption of light by ice molecules. Destructive metamorphism increases the density because of closer packing of small grains, creating more surface area, more refraction and scattering, more absorption, and less light transmitted through the snowpack. Constructive metamorphism results in increased grain size due to growth of bonds between individual ice particles. This causes a reduction in surface area, internal refraction is lowered, and light transmission through the snowpack increases.

The light regime of the subnivean environment changes throughout the winter season as the snowpack changes in depth and density. Wind and settling action of newly fallen snow increases density quickly due to the reduction of pore spaces, therefore light transmission decreases rapidly after snowfall. The absolute light present under 30-40 inches of snow is very low to human eyes, however, it may be critical to the life processes of plants (photosynthesis) and small mammals (timing of sexual maturation and reproduction).
Lesson Five: Thermal Conductivity and Insulative Value of Snow

BACKGROUND INFORMATION

The thermal conductivity of snow is measured as the amount of heat passing through it over a period of time, for a given gradient in temperature between the top and bottom of the snowpack. The lower the thermal conductivity, or transfer of heat, the higher the insulative value. The thermal conductivity of snow is very low relative to other materials, however, this quality is density dependent. For example, older snow is more dense and therefore has less insulative value. The thermal index scale integrates measurements of depth and density to assess the insulative quality of snow cover.

The insulating effect can be measured by the reduction of daily temperature fluctuations underneath the snowpack. At 20 cm of snow, with a density of .1 g/cm³ (grams per cubic centimeter), the subnivean environment is no longer affected by short term temperature fluctuations (Halfpenny & Ozanne, 1989). Once snow depth approaches 50 cm, changes in density are less likely to impact the subnivean environment because the greater depth compensates for the increased density.

Small mammals are restricted in their ability to add insulating fur and fat; therefore, they are highly dependent on the presence of an insulating cover of snow. The strategy animals often use to maintain their heat balance as the air temperature drops is to minimize their contact with the air and to stay below the snow.

Snow has a thermal memory, that is, while the air temperature might be above freezing, the snow temperature might still be well below that. The transmission of heat through a material takes time, and the lower the thermal conductivity, the slower the transmission. In the case of snow, this results in temperature gradients and a thermal memory.

THE BIG IDEAS

- One of the properties of snow is that it acts as a good insulator. This is important for the winter survival of various plant and animal species. This also allows humans to build snow shelters which protect them from the colder outside temperatures.
- The ability of snow to conduct heat through itself can be measured by a mathematical formula.

OBJECTIVES

- Students will learn how snow acts as an insulator.
- Students will understand how heat is transferred through the snowpack.

EE GUIDELINES

Energy

Students begin to grasp formal concepts related to energy by focusing on energy transfer and transformations.

- Trace where energy comes from and goes in examples that encompass several different transfers.
- Explain how solar energy powers the movement
**TIME**
- Introduction-15 minutes
- Investigation 1-2 hours
- Investigation 2-1.5 hours

**PROCEDURE**

Part One: Determining the temperature stability of the subnivean environment.

Note: This is an open-ended inquiry lesson. Your students should have some experience with guided inquiry before undertaking this activity.

1. Students brainstorm questions about the thermal conductivity and insulative value of snow. This can be done either individually, in small groups, or as a whole class.
2. Each student can choose one or two questions which interest them and brainstorms ways in which those questions could be answered through experimentation.
3. Students then develop hypotheses as potential explanations for what is happening and why.
4. Students then develop an experimental design to investigate their hypothesis. Make sure that they identify potential variables and ways to control them.
5. Once students have decided upon and written their procedure, they can make predictions about what will happen.
6. Carry out the experiments, recording all observations and findings.
7. Share conclusions with the class.

Optional: A great deal of learning happens with the first opportunity to carry out an experiment, so offer students the chance to make changes to their design, refine their procedures and carry out the experiment for a second time.

An example of an investigation about how stable the temperature is throughout a snowpack would be to ask the question *How is temperature affected at the top, middle, and bottom, of the snowpack during changes in outside temperature?* Students could set up a study plot where they measure air temperature, top, middle, and bottom snowpack temperatures throughout different weather systems. Include at least one warm weather investigation, and one cold weather investigation for comparison. Record and graph this data.

**Explanation:** A stable subnivean zone experiences only slight temperature changes when there is a large air temperature change. Mathematically, this can be determined with the following formula:

\[
\text{STABILITY} = \frac{\text{Subnivian Change in Temp.}}{\text{Air Change in Temp.}}
\]

For example:
If the air temperature has changed 10 degrees in 24 hours, and the subnivean temperature also changed 10 degrees then the ratio would be 1, indicating low stability.

\[
\frac{1}{10} = \frac{10}{10}
\]
Whereas if the air temperature changed 10 degrees and the subnivean temperature changed 1 degree, then the ratio would be 0.1 and the subnivean environment could be considered stable.

\[ 0.1 = \frac{1}{10} \]

**Part Two: Investigating the Insulative Value of Snow**

1. Have students work in partners and collect a variety of materials which they would like to test for insulative value in comparison to snow.
2. Examples might include dirt, wool, polypropylene, cotton, leaves, straw, etc.
3. Use a standardized container to freeze enough ice cubes for the experiment (one per type of material within each student group).
4. Discuss the variables and ways to control for them. For example, using same weight for each type of insulating material, location of objects, snow depth surrounding materials, etc. You may identify some variables which you can’t control.
5. Students can discuss and decide as a group the various components of the experimental design, such as how to record and determine changes in the ice cube.
6. The design could be as follows:
   - Place one ice cube in a plastic bag. Have enough of these for each type of material being tested.
   - Decide on a location out of the sun, away from buildings, trees, rocks, that is on the snow.
   - Record the starting time.
   - Wrap each of the bagged ice cubes in one piece of the material chosen. Bury another cube in snow, and leave one cube out as a control.
   - Students can write their predictions about which ice cube will melt slowest, fastest, etc. in their science journals.
   - Once the control has melted, check the other cubes. You might want to wrap them up again and check them every 20 minutes to determine rate of melting.

**Assessment**

- Work with the students to develop a set of criteria for evaluating their investigations. Determine specific qualifications for excellent, good, satisfactory, and fair standards. Include such things as answerable inquiry questions, controlling variables, systematic procedures, predictions, conclusions, applying results to new situations.

**Follow Up Ideas**

- Repeat this experiment using different materials.
- Conduct an experiment placing objects at different levels within the snowpack to determine how heat is transferred through from the surface.
- Build snow caves and compare outside and inside temperatures under different conditions.
Module Two: Animals and Winter

The snow world is known as the nivean environment. Snow can either be the key to a particular organism's survival, or it may be the worst enemy. The nivean environment is divided into three categories. The area which is at or above the snow surface is called the supranivean. The area within the snowpack is referred to as the intranivean. The subnivean is the interface between the ground and the snow.

Several forces or vectors of winter combine to create conditions that make survival more difficult. The sun is angled lower in the sky, causing less radiation to be received on the earth during winter. The five major vectors are snow, cold, radiation, energy, and wind, otherwise referred to as the SCREW factor. These forces shape the direction of the evolutionary responses of life forms to winter.

Organisms must respond through expending energy in order to survive the challenging conditions of winter. Responses may be either short term or longer term. An organism may become acclimated to the SCREW factors over the course of a season. These are short-term physiological or behavioral changes that ensure survival in the face of these conditions. The range of possible acclimation is fixed genetically within each individual. Acclimation occurs over days or months within the lifespan of an individual.

Adaptations are longer-term, genetic responses to environmental conditions. Adaptations occur over several generations, and affect populations by allowing better-adapted individuals to survive and reproduce.

An example of this is the lynx. All lynx have evolved large feet. These are adaptations. At various times during the winter, an individual lynx may alter its metabolism during cold spells in order to reduce heat loss. This is acclimatization.
Lesson One: Classifying Organisms Living with Winter

**BACKGROUND INFORMATION**

Plants and animals have learned to deal with the various forces of winter in different ways. Organisms are classified according to how they experience winter and how they have adapted to it over evolutionary time. The commonly used classification system was developed by Formozov and is based on the Greek word for snow, chion. This system is a simple means by which we can identify levels of adaptation to the winter environment which organisms have achieved.

**Chionophobes** - "snow fearers" are organisms which have been unable to adjust to life in the snow. Generally, they are found in warmer regions. Examples are the black vulture, ocelot, opossum. These animals have no specific adaptations to counter the rigors of winter. Although the opossum may be found in cooler areas due to its wide geographic range and successful reproductive strategies, individuals will often be found in spring with the tips of their ears or tails missing due to frostbite. An example of a plant chionophobe would be the palm tree.

**Chioneuphores** - "snow tolerators" are organisms which have adjusted their life to winter and can survive, but have no special adaptations. They are able to take advantage of the environment and may live under the snow or in favorable microclimates conducive to survival. Examples are the shrew, red fox, vole, and elk. During severe winters, many of these animals may not survive.

**Chionophiles** - "snow lovers" are organisms which possess definite adaptations for life in winter. Their geographic distribution is generally limited to winter-dominated regions. Examples are the snowshoe hare, lemming, ptarmigan, and weasel. Several of these animals become white in winter which is an obvious adaptation to the presence of snow. A chinophilic plant example is the spruce tree which has evolved specific adaptations to survive extreme snowfall.

**THE BIG IDEAS**

- Scientists have classified plants and animals according to evolutionary adaptations for dealing with winter.
- Classification systems allow us to categorize organisms in ways that make it easier to understand how they experience winter.

**OBJECTIVES**

1. To sort and classify organisms in a variety of ways.
2. To understand the Formozov classification of organisms' adaptations to winter.
3. To pair different organisms which have evolved similar adaptive strategies together.
**Reproduction and Heredity**
- The characteristics of an organism can be described in terms of a combination of traits.

**Regulation and Behavior**
- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable conditions while living in a constantly changing environment.
- An organism’s behavior evolves through adaptation to its environment.

**VOCABULARY**
- **Adaptation**—evolutionary responses that increase the ability of organisms to survive and reproduce; take several generations to develop.
- **Acclimation**—short term responses to winter; occur within the limits set by evolutionary adaptations.
- **Chion**—Greek word for snow
- **Chionophobes**—“snow fearers”
- **Chioneuphores**—“snow tolerators”
- **Chionophiles**—“snow lovers”
- **Hardening**—a short term physiological process that enables plants to survive winter.

**PROCEDURE**

**Part One:**
1. Divide students into four groups.
2. Hand out the set of matching cards and ask students to generate as many ways of classifying the organisms as possible, with one person in each group recording their ideas.
3. After 20 minutes or so, have each group decide on their three best classification schemes and present them to the class, explaining why they were chosen.

Some of the following questions can be used to promote discussion:
- What are the pros and cons of classifying organisms?
• How/why do scientists classify things in the natural world?
• What categories were common between all of the groups? Why do you think this happened?
• What would have happened if you had more time to do this activity?
• What new things did you learn about these organisms from thinking of different ways to classify them?

Part Two: Introduce the terms and ideas using the slides and lecture notes. Students can either take their own notes, or fill in the worksheet provided. Engage students in discussion of the slides and encourage questions as you go.

Part Three: Have either the same groups or different groups of students go back to the cards. Explain the instructions for the matching game.

Matching Game Instructions
1. Shuffle the organism cards well.
2. Place all of the cards face down on a table.
3. Take turns flipping one card over, then another, trying to find a pair according to the ADAPTATIVE STRATEGY of the organisms.
4. If a match is found, that student gets to keep that pair of cards and try again. If no match is found, the cards are flipped back over and the next student takes a turn.

Assessment
1. Students can use various materials (tubes, cardboard, paper, wire, tin foil, etc.) to construct an imaginary animal that is perfectly adapted for the winter environment. Include an explanation of the different physical and behavioral features of the critter and why they would be advantageous.

Follow up
• Research one animal, plant, or insect that is well-adapted to winter, and one that is not. Develop a display which shows similarities and differences between the two organisms. Illustrate how each has evolved different strategies for their particular environment.
LESSON TWO: SIZE MATTERS!

Background Information

The body size of an animal is one of the most critical factors that plays a role in determining the options available for surviving the vectors of winter. Size helps determine migration patterns, microhabitat choices, body temperature options, and the storage capacity for energy. Generally, the larger the body size, the more options available. Tiny organisms are able to tolerate freezing; small organisms can tolerate freezing or hibernate; moderate and large organisms are able to tolerate cold temperatures, hibernate, or migrate.

Migration

One of the choices available to some organisms is to avoid winter by migrating to warmer climates. Whether migration is possible is largely determined by body size and locomotion abilities. Flying is the most efficient form of locomotion, but is obviously not available to all organisms. Long distance migration, therefore, is energetically feasible for most birds. Walking is only half as energetically efficient as flying, and running is one fifth as efficient. Long distance migration for land animals is only possible for the largest ungulates like caribou.

Microhabitat Choices

Smaller organisms are capable of avoiding the vectors of winter by finding microhabitats under snow, in the subnivean environment. Insects can use barks of trees, fur of larger animals, or bury underground to protect themselves against harsh conditions. Larger animals are capable of moving to less hostile microhabitats, such as lower elevations, to increase their chances of survival.

Body Temperature Options

To maintain a stable body temperature, organisms must be able to produce heat by bulk of body tissues, muscles, and metabolic tissue. The larger the organism, the greater the heat-production capacity. Heat production must not be exceeded by heat loss from the surface of the organism. Temperature stability is determined by the ratio between capacity for heat production, determined by volume, and the potential for heat loss, determined by surface area. Size ratio of surface area to volume is critical to heat retention. Smaller organisms have less potential for heat production and greater potential for heat loss, therefore, body size is a limiting factor in the choice to maintain a stable temperature.

Storage Capacity for Energy

The smallest organisms, such as insects, are unable to store energy in the form of fat, and do not have insulation such as fur or feathers. Larger organisms are able to continue to produce heat through the metabolism of stored fats, and are able to slow the loss of this heat to the colder environment through insulation.

References


The Big Ideas

- The ratio of surface area to volume can be calculated and is a critical factor in heat production and loss in animals.
- Surface area plays an important role in heat loss of organisms. If volume is equal, then the greater the surface area, the more rapid the loss of heat.
- Animals counter-act the loss of heat using a wide variety of strategies.
OBJECTIVES
1. Students will formulate and use an experimental design that tests their predictions about surface area and heat loss. They will evaluate their own and their peers' experiments, suggest changes, make revisions, and repeat procedures to compare results.
2. Students will understand the role that surface area and volume, and the relation between the two, play in an animal's ability to maintain body temperature. 3. Students will make predictions about possible behavioral responses animals might use to counteract the heat lost through surface area.

EE GUIDELINES
Organisms, populations, and ecosystems
- Describe how organisms differ in how they use energy for growth and metabolism.

Heredity and evolution
- Identify some basic traits of organisms. Explain how specific traits increase the likelihood that individual organisms will survive and reproduce in particular environments.

Designing Investigations
Learners design environmental investigations to answer particular questions.
- Connect questions with appropriate types of inquiry.
- Define the scope of inquiry, identifying the main variables and phenomena to be studied.
- Select tools that are appropriate for their environmental investigations based on the question asked and the type of information sought.

MATERIALS
Student science journals
Sets of 2 different shaped containers
Kettle
Candy thermometers
Small and large cubes

TIME
Discussion-15 minutes
Designing Experiments/discussion-20 minutes
Predictions/Experiments/Recording and graphing results-50 minutes
**VOCABULARY**

**Bergmann's rule**-geographic races of species possessing larger body size are found in the cooler parts of the range.

**Allen's rule**-the extremities, such as tail, ears, and bills of animals are relatively shorter in the cooler parts of a species' range because small, compact extremities have reduced capacity to radiate heat.

**Temperature transient**-determines how rapidly an organism cools off or heats up. Small organisms have short transients as they cool off and heat up rapidly.

**PROCEDURE**

**Station One: Calculating Surface Area/Volume ratios**

This lesson is designed to illustrate how different sizes of blocks, representing organisms, result in widely varying surface area/volume ratios. This particular ratio is important in terms of an animal's ability to retain heat and survive low ambient temperatures. This activity can either be done as one station which students go to, or as a demonstration in front of the whole class. This procedure is outlined for students to use independently. Provide students with two different sized blocks (one that is 1inX1in, another 4X4in).

**Student Instructions**

1. Imagine that each of these blocks represents an animal. If you were to place each of these creatures out in the cold, which would lose heat faster? Keeping in mind that volume helps determine heat production and surface area determines heat loss, which creature is at a disadvantage due to its size? Why? Write your predictions in your science journal.

2. Determine the area of one face of each of these blocks (length X width).

3. Now calculate the total surface area of each of these blocks (add all of the sides).

4. Calculate the volume of each of these blocks.

5. For surface area:volume ratios, divide the surface area by the volume. Figure this out for each of the blocks.

6. How much more volume does the large block have for generating heat than the small block?

7. How much more surface area does the small block have for losing heat than the large block?

8. Which organism is at an advantage for dealing with winter conditions?

9. Refer back to your predictions and explain what your thinking is about surface area: volume ratios in organisms living in winter environments.
Teacher Answer Key
2. Small block: 1 insq.(1X1) Large block: 2insq.(2X2)
3. Small block: 6insq.(1per sideX6 sides) Large block: 24insq.(4per sideX6 sides).
4. Small block: 1in3.(1X1X1) Large block: 8in3 (2X2X2)
5. Small block: 6 (6/1) Large block: 3 (24/8)
6. The large block has 8 times more volume for generating heat than the small block.
7. The small block has twice the surface area for losing heat than the large block.
8. If an organism has a high surface area: volume ratio, it will be at a disadvantage (small block 6:1; large block 3:1) because it has more surface area to lose heat from and less volume to help generate heat.

Assessment
1. Check students’ answers for accurate calculations.
2. Evaluate initial predictions and follow-up responses for changes in thinking based on evidence gathered from activity.

Station Two: Experimenting with Heat Loss
This activity takes students outside to experiment with how different shaped containers effect heat loss in cold environments.
1. Have students choose a location that is preferably out of direct sunlight, on snow or cold ground surface, where they will place two different containers filled with the same amounts of boiling water (Fig. 7).
2. Students can boil a kettle full of water. While they wait, have them make some predictions about their experiment in their science journals. You can also ask them to discuss their ideas with partners or in small groups.
3. In a whole class discussion, ask students to make some suggestions about carrying out an experiment which will test how surface area affects rate of heat loss. Ask them to think about what variables may exist and how to control for these. They can generate some of these ideas in small groups before discussing with the class, also.
4. Allow different groups to determine their experimental design, and try to provide them with the materials they need to carry out their ideas about controlling for variables. (For example, someone might think about wind and want to build a barrier out of cardboard.)
5. Taking into account the different student-generated ideas, the basic format for this experiment is to have the two containers (one shallow and wide, another tall and deep) in similar locations, pour the same amount of boiling water into each one, then use thermometers and a stop watch to determine the rate of heat loss in each one.
6. Students can make a table to record their data, then graph their results.
7. Give each group a piece of chart paper to record their most valuable findings, then have them share how they carried out their experiment, what they predicted, and what their results showed with the rest of the class.
ASSESSMENT

In their science journals, have students answer the following questions:

- How does surface area play a role in heat loss?
- What other factors affect heat loss in an organism?
- What adaptive behaviors do you think organisms might use to counteract the loss of body heat through the surface of their skin?

FOLLOW UP IDEAS

- Students can generate a table and graph prior to carrying out the experiment to predict their results. These can be recorded in their science journals with explanations for their predictions.
- Students can evaluate their experimental design—what worked, what needed to be changed—and repeat the experiment with their revised procedures.
- Students can trade experimental designs and try to repeat the procedure of their classmates to see if they get matching results. The teacher can talk about the value of this step in the scientific method.

Container A  Container B

Start
Temp.

2 min
Temp

3 min
Temp

4 min
Temp
Lesson Three: Fur-Bearing Mammals and Winter

Background Information

Mammals have evolved different specializations in order to cope with wide variations in environmental conditions. It is remarkable to think about all of the places that mammals are found, from tropical jungles to the Arctic tundra, and to consider the dramatically different conditions under which they can survive. Mammals are homeothermic endotherms, that is, they produce their own internal heat and regulate their own body temperatures. This requires specializations in physiology, anatomy, and behavior. Some of these include a cardiovascular system with a four chambered heart, mammary tissue, lungs that are partitioned, numerous fused bones for rigidity, a secondary palate to allow breathing while eating, modifications in dentition to allow feeding on a variety of food, depth perception, and hair.

Hair, more commonly referred to as fur, is unique to mammals and not found in any other group of living things. This evolutionary specialization provides several advantages. One of the primary advantages, particularly with respect to mammals living in colder regions, is insulation. There are two types of fur on a mammal’s body. The underfur, like 'down', is very dense. The coarse overlayer, act like guard hairs and can better handle abrasion, protecting the underfur from damage. These guard hairs are replaced often and animals spend time grooming to keep the underfur clean and dry. All of these hairs trap air molecules, which get warmed from body heat, thereby providing insulative properties. Hairs can also protect the animal by providing a physical barrier, and also through coloration. (Did you know that a porcupine’s quills are simply modified hair structures?)

Adaptive Coloration in Furry Mammals

The question of why some mammals change the color of their fur in winter is an interesting one, and more complex than one might think. There are still many unanswered, interesting questions about this. It has been suggested that dark coloration absorbs more sunlight and, therefore, would also radiate more heat and be a disadvantage to homeotherms in cold climates. We know that white radiates less heat, which is a possible ecological explanation for the reduced pigmentation found in animals closer to poles, with northern races lighter in color than southern. This, however, could only be true if black objects heated more substantially as result of greater absorption of sunlight (assuming two emit heat equally).

The radiant heat loss from any object is largely a function of its temperature, and the homeotherm maintains constant body temperature whether white or black. This means that even if a dark animal absorbed more heat, it would likely compensate for this by other means to maintain a constant core temperature.

An experiment with all white finches and ones painted black demonstrated a balance between absorption and metabolism. It was found that all black birds metabolized at lower rate, therefore enjoying an energetic advantage from the absorption of light. This would make it seem better to be black in the north than white, which goes against what we actually find.

Another explanation for light coloration patterns found in snow-covered areas is that it functions as a cryptic advantage, allowing these animals to be camouflaged by their environments. This makes intuitive sense: however several questions remain. What advantage is this to the arctic fox, which is a scavenger with little worry of predator avoidance? What is the advantage of turning white for weasels when they spend most of their time in winter hunting small mammals under the snow where visual clues are unimportant to predator or prey? Why does the arctic hare maintain its white coat in some northern areas throughout summer where it becomes highly conspicuous?

One study of species of all white and all black birds in western North America revealed some interesting conclusions that draw a relationship between coloration and insulation. This researcher found that insulation on all white birds is better. The all white birds spent the night in the open, whereas almost all of the black birds roosted under cover, thereby benefiting from black-radiation heat from their surroundings. This suggests that white coloration in birds may serve to minimize heat exchange with the environment. Heat loss is reduced through increased insulation while at the same
time reduced heat gain through increased reflectance would help prevent overheating when these birds are active during the day.

There is a possible relationship between color and insulation. Whiteness is usually due to the absence of the pigment melanin, which leaves hair very hollow. The light gets scattered and reflected in this hollow space, rather than being absorbed, and thus appears white to the human eye. The same is true with white feathers. Such hollow spaces also reduce thermal conductivity of fur and feathers, resulting in better insulation for white animals.

This color change is triggered in some species by temperature, in others by photoperiod. The timing of this change is important. If an animal changes to white too early, it becomes conspicuous in the still green and brown environment. An endogenous clock is one that is internal to the body. This timing device helps animals prepare for winter. Hibernators "know" to put fat on and others to change color. This timing is aligned to environmental cues rather than an exact calendar. It is complex and doesn't always work exactly. Evolutionary pressures are constantly refining timing. Snowcover may be the primary selective pressure that led to the evolution of seasonal color change, perhaps increased insulation is just a secondary advantage.

The coats of weasels, ptarmigans and snowshoe hares change from shades of brown to white for the winter. For weasels, this involves a complete molt in which hair is lost and the new coat replaces the old one. In snowshoe hares, only the tip of the hair turns white, while the base remains grey. This means that it does not have to go through a complete molt in fall. The arctic hare remains white during summer.

Fur thickness was once thought to predict the severity of winter, but it is now understood to reflect the weather conditions of the previous summer. If it was hot and dry, fur is thinner. If it was a wet and cold summer, then fur is thicker and more dense.
Regulation and Behavior

• Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part from experience.

• An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces, and responds to danger are based in the species' evolutionary history.

Diversity and Adaptations of Organisms

• Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.

BIG IDEAS

• Many mammals that live in winter environments have fur coats that change color according to the season. This is an adaptive strategy which they have evolved to increase their chances of survival.

• Scientists can hypothesize about the selective pressures which resulted in certain physical attributes of animals that we find today.

• Evolution is an ongoing process.

• Close observation of animal furs can reveal details from which to make educated guesses about other life history traits.

OBJECTIVES

1. Students will improve their observation skills.
2. Students will gain skills in formulating questions that can be answered through investigations.
3. Students will improve their understanding of the characteristics of the fur covering of winter adapted animal species.

MATERIALS

Fur samples
Magnifying glasses
Microscope
Journals

Chart paper
Blindfolds

TIME

Two 60 minute classes.

VOCABULARY

Pelage-covering of hair or fur
Endogenous-internal to the body
Photoperiod-length of the dark period of each night, which changes from season to season
Molt-replacing old hairs with new ones
Homeothermy-maintaining constant body temperature
PROCEDURE
1. In small groups or as a class, have students brainstorm ideas about the following, recording their answers on chart paper:
   - What are problems that animals face in winter?
   - What are different ways that animals might deal with those problems?
   - What is insulation? List as many forms of it that you can think of?
Students can present their ideas for discussion. Encourage them to explain their thinking about the ideas they've generated and challenge them to hypothesize about why things are as they understand them to be.

2. Set fur samples (each one tagged with a letter or number, not the species name) out on different tables and have students examine each one carefully. In their winter journals, instruct them to sketch each fur and write down detailed observations (e.g. smell, magnified view, feel, etc.). Do not focus on guessing the names of each animal, encourage students instead to learn everything they can about the texture, feel, look of each pelt.

3. When students have examined each fur carefully, and finished recording their observations, have them put their journals away and get into partners or trios. One student can volunteer to be first to be blindfolded. The partner will place the hands of the blindfolded person against one of the pelts and that student will try to guess which one it is. Each pair can take turns with 2 or 3 different pelts.

4. Either alone or in pairs, ask students to generate 2 or 3 inquiries about fur-bearing mammals and winter. Encourage students to formulate questions that they could investigate answers to through experimentation. Ask students to list at least 3 hypotheses which would answer the question they choose to focus on. Then, students can design an investigation to test their question. Be sure to discuss possible variables and ways that they can control these.

Example
Inquiry: What is the advantage of having white fur in the winter?
Hypotheses
1. It helps animals blend with the snowy environment so they won't be eaten by predators or seen by prey.
2. They don't have enough nutrition to keep their fur dark.
3. White fur coats are warmer than dark fur coats.
Possible investigations:
   - Find a location where animal activity is likely. Place a white pelt and a dark pelt close together with bait under each fur. Wait to see which one a predator is more likely to take.
   - Take two containers with boiling water in them and surround one with a white pelt and another with a dark pelt. Place both of them in similar locations that are cold, preferably on the snow. Check temperatures every 20 minutes to determine which has better insulative properties.

Students can write more detailed procedures, and a list of variables and possible ways to control them.
5. You can have students either carry out their investigations or, if time is short, they can evaluate one another’s plans for answering their inquiries. This can be done either informally through verbal discussion or by way of a peer evaluation form.

**ASSESSMENT**

- **Student-generated:** In small groups, have students write in point form the various criteria that would define the quality of an investigation. Provide four possible headings such as excellent, good, satisfactory, and fair. Groups can share these ideas and, with teacher input, decide upon the criteria for evaluating all of their investigations. Students can use these in their peer evaluations, and the teacher can use the same form when evaluating student work.

- **Teacher-generated:** You can formulate a rubric which outlines the criteria for excellent, good, satisfactory, and fair investigation designs and hand these out prior to the students starting work on part 4 of the above activity.

- Evaluate journal entries for writing skills, observational detail, originality, detail in sketching pelts.

**FOLLOW UP**

- In small groups, provide two pelts for students. On chart paper, ask students to generate a list of comparisons between the two pelts under the headings 'Similarities' and 'Differences'. This is another method of developing thinking skills and more in-depth knowledge of particular fur characteristics.

- Students can carry out their investigations by writing up the procedure, collecting the materials, recording and interpreting data, and drawing conclusions. They can then evaluate their own investigations and recommend changes to refine the procedures.

**References**

*Life in The Cold.* P. Marchand


The subnivean world can be either a haven for critters, or a death trap. Under certain conditions, it is a hospitable escape from predation and the many other rigors experienced by larger animals braving the winter elements on top of the snow. The subnivean environment is relatively warm, has fewer temperature fluctuations and the winds are nonexistent. Animals can survive winter without having to evolve energy-draining mechanisms necessary for life under adverse conditions. On the other hand, the subnivean world can mean sure death for organisms under different conditions. The dangers include increased carbon dioxide, flooding, ice layer formation, and predators moving about in elaborately constructed tunnels. Dangers can be highest during critical periods of fall and spring.

There are many organisms that remain active beneath the snow throughout the winter. Different plants store food that is available for consumption by herbivores. Numerous and varied insects provide a rich protein source for insectivores. This intricate and complex world has been characterized by scientists as an ecological food web for winter-active subnivean animals. It is handy to represent these relationships as a pyramid; however, it is actually a complex web with interrelated components.

The primary producers of food are plants and fungus. These can serve as detritus or as living material which others feed on. Detrivores are organisms that feed on detritus, which is rotting plant material. Fungal mats feed springtails and flies. The next level is that of primary consumers. These can be herbivores, such as aphids and leaf hoppers which feed on winter-green plants. This layer of the energy pyramid can also include mites, spiders, predatory beetles, and wasps. Primary consumers are fed on by secondary consumers, also known as primary predators. The main member of this level are the shrews. These little critters basically feed on anything that moves. They are the smallest mammals on earth with a metabolism that is so fast that it requires they eat twice their body weight every day. It is now known that shrews prey mostly on the large number of winter-active insects under snow.

Shrews inhabit a wide variety of niches and have even been found in Colorado at elevations higher than 14,000 feet. Shrews do not hibernate or go dormant and are able to feed throughout winter, regardless of the conditions. Shrews may take up to 50 percent of their winter diet in the form of conifer seeds or beechnuts and have even been found hoarding these items in winter caches. Mice and voles are also considered a part of this level. They are primarily herbivores or granivores (seed eaters), but will eat an insect if it runs across their path.

This lesson is based on principles involved in the energy pyramid. There are two basic laws of energy which this game helps students grasp through direct experience! The first law of energy is called the law of conservation of energy or the first law of thermodynamics. In any physical or chemical change, movement of matter, or change in temperature, energy is neither created nor destroyed but merely transformed from one form to another. The second law of energy or thermodynamics states that in any conversion of energy from one form to another, the initial form of energy is always degraded to a lower quality, less useful energy, usually low temperature heat that dissipates into the environment. This second law is often referred to as the law of degradation of energy (Miller 1991). The game Winter Predator-Prey illustrates this second law in terms of energy moving through the levels of the pyramid of winter-active animals. At each level, an animal will consume some form of energy, whether that food source be plant or another animal. An estimated 90% of the available energy during each transfer from level to level is lost to the environment and no longer useable. This explains why we see so many more herbivores than upper level carnivores. Top-level predators have a greater challenge in meeting higher energy needs.
Energy is degraded with each transfer from one organism to another. Only 10% remains in a high-quality, useable form. Most of the remainder dissipates as quality heat, low-quality energy.

**BIG IDEAS**
- In any change of energy from one form to another, it is always degraded to a lower quality, less useful energy.
- Energy moves through ecosystems in a one-way flow; matter is cycled through ecosystems. Food chains are channels for the one-way flow of some of the sun's energy through the living components of ecosystems.
- At each transfer from one trophic level to another in a food chain, energy is transferred and degraded and the availability of high-quality energy to organisms at the next trophic level is reduced. (Ecologists estimate an average of 10% of high-quality chemical energy is transferred and stored in a useable form for the bodies of organisms at the next level.)

**MATERIALS**
- Winter Predator-Prey Cards
- 2 whistles
- fabric strips/bandanas
- Rule Poster
- 4 dry erase pens
- food/water cards
- dry erase board (optional)
**TIME**
Introductory activity-30 minutes
Game-30 minutes
Debrief-20 minutes

**VOCABULARY**
Detritus-dead plants, rotten logs, fungal mats; serve as food for detrivores.
Granivores-seed-eating animals.
Herbivores-plant-eating animals.
Producers-organisms that are capable of producing their own food; plants.
Consumers-organisms that require an outside source of food, whether plants or animals. All animals, including humans, are consumers.
Subnivean-below the snow.
Critical Periods-times during the year which tend to result in the greatest animal mortality due to heightened environmental stresses, and/or the importance of meeting needs to ensure success at other times; spring and fall.
Predation-when an organism (predator) captures and feeds on all or one part of another organism (prey).

**First Law of Thermodynamics** (Law of Conservation of Energy)-Energy can neither be created nor destroyed, only changed from one form to another.

**Second Law of Thermodynamics** (Law of Degradation of Energy)-In any conversion of energy from one form to another, high-quality, useful energy is always degraded to lower quality, less useful energy.

Energy Pyramid-An illustration of the energy flow within a food chain. The greater the number of trophic levels in the food chain, the greater the cumulative loss of useable high-quality energy. Typically, 90% of usable energy is lost to the environment at each trophic level.

**PROCEDURE**
Option One: Introduction
1. To introduce the idea of the energy pyramid, present each small group of students with a set of winter predator-prey cards and ask them to move the cards around and decide together on a way to illustrate how they think energy moves amongst all the different cards.
2. After discussing the students' ideas, try to draw out the idea of energy flowing through different levels of organisms, starting with the sun, then to plants, then producers (herbivores), primary consumers (omnivores), secondary consumers (predators), tertiary consumers (top-level predators). The following questions may help students clarify this concept:
   - What is the original source of energy on the Earth? (sun)
   - What organisms are capable of making their own food? (plants) Why are they called producers?
   - What organisms occupy the next level of energy flow? (herbivores/primary consumers) Where do they get their energy from? (plants) Who do they pass it on to? (carnivores)
• What organisms eat these creatures? (other carnivores/predators)
3. In order to explain the concept of the energy pyramid, you can ask students which organisms they are most likely to encounter and which ones are they least likely to see from day to day. They are most likely to see plants, then herbivores because they are most abundant. Omnivores (eat plants and animals) are the next likely to be seen, with top-level predators, such as mountain lions being the least frequently seen. Ask students why the populations of herbivores are greater than carnivores? This discussion can lead to the concept of how energy flows through living organisms, the pyramid as a way to conceptualize this, and how at each level, there is less energy available due to degradation and loss.

Option Two: Introduction
1. Use the winter predator-prey cards and tape one card to each student's back, without them seeing it. Instruct all the students to ask their classmates questions with yes or no answers to try to guess what is on their own card.
2. Once everyone knows what their card is, have them as a class stand in a formation which shows how energy enters and leaves each organisms. You can start with such questions as:
   • What do all of these things need (except sun) in order to survive? (food or energy)
   • Where does each one get it from, and give it to?
   • Which organisms has the easiest time acquiring energy? (plants and herbivores)
   Which ones have the most difficult time? (carnivores) Why? (availability of a source, how narrow their diet choices are)

This discussion can help students clarify and begin to formulate the idea of an energy pyramid, and the second law of degradation of energy. Use a dry-erase board to draw the pyramid with each level of organisms, illustrating the flow of energy, and providing examples of local animals at each level. (See Poster for example)

Winter Predator-Prey Game
Describe the rules of the game to students (Use the Rule Poster for students to see):
Now we are going to play a game called Winter Predator-Prey where each of you is an animal that has to meet certain needs for survival, while either capturing prey, or avoiding being eaten.

These are the rules of the game:
1. Each of you will either be an herbivore, an omnivore or a predator. Give me an example of two herbivores, one omnivore, and one predator that live around here and are active in the winter. (e.g. mule deer, snowshoe hare, aphid/shrew, coyote, fox/bobcat, lynx, marten, weasel).
2. Now divide yourselves up in a way that represents how you think the population ratio is. Let the students try to figure this out then get into groups. (e.g. For a class of 25 students, 3 carnivores, 8 omnivores, 14 herbivores.)
3. To identify each other, the carnivores will wear a bandana on their heads, and the omnivores will wear one on their arms.
4. There are 6 water cords and 6 food cards that are hidden all around the playing area. (Identify the boundaries for students, an outside area with different objects such as shrubs, trees, buildings, where cards can be hidden and students can run).
5. You must travel with your group and attempt to find the different cards. When you find one, you will EACH initial it with your dry erase pen. Try to find as many as you can.

6. While you are doing this, the predators are trying to capture prey. In addition to the food on the cards, they need to find live organisms to consume. The omnivores can also try to capture any of the herbivores. If either the carnivore or omnivore group is ready to launch an attack, they must BLOW the WHISTLE ONCE to signal attack. From that signal, they have 30 seconds to carry out the attack. They must run as a group and try to tag members of the other group. They can only capture as many or less than the size of their own group. (e.g. three carnivores cannot capture four herbivores, only 3 or fewer). Someone in the group needs to time the 30 seconds and BLOW the WHISTLE TWICE to signal the end.

7. The only time any group can separate is if they are being attacked. When the attack is over, they must regroup.

8. Anyone captured must join that group and identify themselves with a bandana. (Extras carried by each group).

9. Animals CAN be attacked while they are eating or drinking (initially cards).

10. Each group can assign someone to remember/record how many of each card they were able to find and sign.

After students understand the rules of the game, have them use their science journals to each write their prediction about how the population numbers of each group will change during the game.

PLAY the game. Give students about 30 minutes playing time. Monitor for safety, staying within the boundaries, etc.

Debrief:
- Give students a chance to talk together about the game, return equipment, and get settled.
- Using the dry erase board and the pyramid drawing, ask each group to state their pre-game population numbers, and their post-game population numbers.
- Now inform each group of what their minimum requirements were for sustaining their populations:
  - *Herbivores-needed to sign 4 food cards and 4 water cards.
  - *Omnivores-needed to sign 5 food cards, 4 water cards, and end with at least 4 captured prey (half the size of their group).
  - *Carnivores-needed to sign 6 food cards, 4 water cards, and end with 6 captured prey (twice the size of their group).

  Groups that did not meet these requirements get wiped off the board. Discuss with students why the requirements are higher for each group. (Due to the reduced availability of energy at each tertiary level, and the increased number of prey needed to survive.
- Compare the final population numbers with what students' predicted. How are they similar/different? Why?
- Ask students to describe how they think the game is true for the natural world and how they think it is unrealistic.
ASSESSMENT
1. Research local endangered animals and draw an energy pyramid with those examples. Describe the relationship between the food chain concept and why these animals are endangered.
2. Draw the energy pyramid in your science journals using different examples of local animals. Write a paragraph describing how energy flows from the sun to the top-level predators using the correct terminology.
3. Define in your own words, the following terms: energy pyramid, food chain or web, laws of thermodynamics.

FOLLOW-UP IDEAS
1. Design improvements for the Winter Predator-Prey game to make it more realistic in terms of how things are in the natural world.
2. Find a different example of the Second Law of Energy that relates to winter ecology and design a lesson to teach to the class.
3. Using the second introduction option, take a ball of string and have students stand in a circle with their cards visible. Have each student take turns taking the string and handing it to someone else, describing how they are ecologically related. Once everyone is connected via string, identify an event or force that would remove one animal (e.g. overtrapping leads to endangered lynx). Pull that person out of the circle and look what happens to the web.
4. Research the life history of different top-level predators. Predator Conservation Alliance is an excellent resource for this. Develop campaigns to promote the health and sustainability of these creatures.

References
*Predator Conservation Alliance (pca@predatorconservation.org)
Lesson Five: Animal Tracks

Tracking is an age-old method of understanding animal behavior in the natural world. Our ancestors used keen observation skills to hunt down critical food sources for their families. They were able to not only identify the species of animal from the track, but distinguish size, weight, age, sex, state of health, time it passed, where it came from, where it was going, and which way it was looking, among other details (Brown 1999). Today, in our technological society, we are less dependent on the ability to read animal tracks, and much of this skill and understanding has thus been lost.

Winter is an extraordinary time to ponder the movements and activities of animals as they leave distinctive clues of their passing with markings in the snow. Students get excited as they learn some of the basic principles of tracking, and launch on a detective mission from piecing together the scattered clues.

Helpful Hints on Tracking

- Prints are rarely perfectly formed as seen in guidebooks. When you find a reasonably clear print, start by measuring the length and width, counting the number of toes, checking for claw marks, and noting how far away they are from the body of the print.
- Try to collect these measurements on several prints to find an average.
- Check out the pattern which the prints make together as a track. See if you can distinguish the fore from the hind prints (fore is usually larger). Look at where the fore and hind prints register, which is in front, which is behind, which ones overlap.
- Follow the track for a distance and look for other clues. Try to determine where it leads and what this tells you about the critter. Does it lead into a burrow? up a tree? into the river? These clues can narrow down your search for identifying the species if you know something about the niches which different animals occupy.
- Wake up to the bigger picture! Have a look around for other signs of passing: tufts of hair, nibbled plants, urination marks, scratches on trees, dead carcasses, bones, etc. Start to piece together the tale of this animal’s day and winter comings and goings. Put yourself inside the critter’s head and see the world from a different point of view.
**Big Ideas**
- Tracking is a way of developing a greater awareness for one’s surroundings.
- Animal tracks reveal a great deal of information about a particular species, their behavior, and how they are interacting with the environment.
- Before looking at specific tracks, one can make predictions about where animals might be based on an understanding of animal needs and behavior in a particular environment.

**Objectives**
1. To gain an understanding of the variety of information that can be gathered from close observation of prints and tracks.
2. To transfer skills in reading prints to careful observations of animal tracks in the outdoors.
3. To appreciate the connection between identifying tracks with skills in nature observation and awareness of one’s surroundings.
4. To gain an understanding of local animal populations, their habitat preferences, life histories, and daily behaviors through research and reading tracks.

**Vocabulary**
- Print-a single impression of an animal’s footprint.
- Track-a series of prints, also referred to as trail.
- Tracking-the practice of observing prints, tracks, and animal signs in the outdoors.
- Stalking-moving towards an animal, without it being aware of our approach.
- Gait-the pattern left of the coordinated movement of an animal, includes walk, trot, gallop.
- Walk-each foot moves independently of the others, two or three feet always on the ground.
- Trot-two diagonal feet move at the same time, leaves a symmetrical track.
- Lope-relatively slow gallop, one airborne phase, (also called canter).
- Gallop-an asymmetrical gait. There are two known types: Rotary where the pattern of stepping goes from right front, right back, left back, left front in a circular rotation. The Cross gallop is where the sequence of footfalls is a cross or tranverse-right front, left back, right back, left front.
- Stride-distance from where one footprint appears to where same foot makes next print (two full walking steps)
- Sexual dimorphism-When there is a size difference between males and females within a species; usually female smaller than male.
- Digitigrade-Mammals that walk on their toes, such as coyotes.
- Plantigrade-Animals that roll their whole foot on the ground from heel to toes; generally move slower than digitigrade and spend less time trotting or galloping.
- Pads-Provide traction and absorb shock on mammalian feet.
  - Toe pad-found directly under the toe.
  - Plantar pads-behind the toe pad, also called interdigital pad.

**Materials**
- Blindfolds
- Book- *The Other Way To Listen* by Byrd Baylor
- Rulers
- Tracking Cards
- Plastic Boxes-Print Trays
- Fill (Sand, gravel, mud, litter, etc.)
- Science Journals
- Track Observation Forms
- Track Study Cards
PROCEDURE

Part One: Reading Prints

The purpose of this section is to help students begin to understand the print impressions left by different motions in a controlled setting.

1. Use the plastic trays provided, or make 2ft×2ft×6 inch trays and fill them with sand or some type of soft soil. (You could even use litter!). Make sure they are filled so that each one is a couple of inches deep.

2. In partners, challenge the students to make a single print in a variety of ways for their partner to guess. Start off simply with a downward press, as clearly made as possible. Work up to adding motions such as forward, backward, twisting each way. Vary the speed with which they are made from slow to fast. Partners can switch making and guessing each print.

3. Group all of the students together and ask them what patterns they have noticed.
   - Which type of print is easiest to distinguish?
   - What did they learn about the force of the body and the sign it makes in the print?
   - What patterns did they observe?
   - How might this be similar/different when observing animal prints?

4. Once students have shared their observations as a group, ask half the class to leave the room and have the other students each make a single print in each box, then sit in a circle with their shoe bottoms visible. The other students can enter the room, observe the prints, and try to match the person with the print. This can be done several times with different students leaving the room to guess.

5. Repeat #4 without shoes. Have students make single prints with a bare foot and ask other students to try to match the foot with the print. This is a more advanced skill. To challenge students further, have the print makers add motion to the print. The guessers can identify the maker, in addition to the direction and speed they were moving.

6. Gather students once again and ask them to identify any other observations they have made about reading prints. Share these with the class. If you want, you can list the 'principles' of tracking that students generate.

7. Now go outside and ask students to find a different partner. One partner can make a TRACK in the snow without the other person watching. The track maker can vary speed and direction-walking, running, hiding. The partner then tries to follow the track and make as many observations as possible about the maker. Extend this activity by having the maker think of an animal and try to mimic what they expect their track behavior to be like. For example, would the animal make a track leading to a tree because it's a climber?

8. Once students have had enough time to make and guess a few different track patterns, gather them together to discuss what they learned about reading tracks on the different surfaces found outside.
   - What type of surface was easiest to read?
   - Which was most difficult?
• What could you guess about the overall pattern of the track as opposed to a single print?
• What does this mean for reading animal tracks?
• Did you find any other clues that gave you information beyond the prints?

9. You can have students spend a few moments recording their observations, ideas, conclusions, and questions in their science journals.

Part Two: Observing Signs
The purpose of this section is to help students gain a broader awareness of the importance of looking at all of the signs and clues of an animal's passing, beyond just the tracks.

1. Give the students 5-10 minutes to wander about an outside area to hunt for signs of animals, encouraging them to look for clues other than tracks. Ask them to keep what they found a secret.

2. Ask students to join together in groups of three.

3. One student can volunteer to be the first to be blindfolded. The other students need to gently lead that person to one of the clues that they found earlier. When they arrive near the spot, carefully move the blindfolded person close to the clue, and ask them to lift their blindfold for 2-3 seconds, then place it back over their eyes.

4. Repeat this with the same person 2 or 3 times so that they 'photograph' different animal signs in their mind.

5. When they have seen all three, ask the students to move the blindfolded person back to a central location and circle with the rest of the group. They can then describe the three photos which they took in their mind to the rest of the group. This person, with the help of other students, can try to guess what animal made each sign and why they think so.

6. Read Byrd Baylor's *The Other Way To Listen* to the students.

7. After this activity, assign a small area to each student (approximately 5-7 yards in circumference) with their science journal. Giving everyone 15 minutes, have them draw and/or record all of the signs and sounds of animals that they can find within their area. Encourage them to be very still and quiet for the first few moments to observe sounds.

8. Optional: Ask students to share some of what they observed during their time alone.

Part Three: Putting It All Together
1. Introduce students to the Tracking Cards and the Track Observation Forms. (You can also use the posters as visual aids.) Discuss some of the characteristics of different families of animals and their prints and track patterns.

2. Use the Study Cards to play an elimination guessing game to familiarize students with identifying characteristics of different tracks.

3. Give each group of 4-5 students a set of the blank Track Cards. Ask them to categorize them according to similarities. Then, after discussing the patterns that students observe, hand out the Tracking Cards and introduce the characteristics of different animal families.

4. Another option for introducing identification of tracks is to hand out the written generalizations of each mammal group and ask students to draw the print described. They can then compare their drawings to the Tracking Cards to note the similarities and
differences. Remind them that the written descriptions are only generalizations and variations will occur between animals within that group. For example, the fox and wolf will be distinct from one another but will share certain characteristics.

5. In partners or small groups, students can take their Tracking Cards and Track Observation Forms outside to search for tracks and signs of animals. Encourage students to fill out their forms, taking measurements and observing as many other signs of animals as possible.

6. Bring students together to debrief what they found. This activity can be repeated on numerous occasions, under a variety of ground surface conditions to provide students with enough practice in reading tracks to being to be proficient.

ASSESSMENT
Give students a variety of scenarios laid out on the snow using life-size print copies. Ask them to identify the species, describe the habitat and why these species would be found there, hypothesize about what each is doing, where it's going, how it is interacting with other species and why.

FOLLOW UP
- Combine a lesson on pelts with a tracking activity. Have students look at the pelt to predict the type of tracks that an animal would make.
- In A Field Guide to Mammal Tracking in North America, there is an excellent section on reading tracks (p. 106-128) with pictures, clues, activities and the answers.
- Older students can create a treasure hunt for younger students by either finding or placing a series of animal signs and/or prints on a map. At each 'sign', a clue to where the next one can be found. Students can use information about the habitat, needs, and behaviors of each animal as part of their clues.
- Invite a local trapper/hunter to teach students more about animal tracks and signs. Dan Leonard provided the pelts for these trunks and has led various seminars on tracking with children and adults. He can be reached at 406-777-1085

References
*Dan Leonard-local tracking expert
TRACK OBSERVATION FORM

Track Record

Date __________________________ Location __________________________

Weather __________________________ Habitat __________________________

Surface __________________________ Species __________________________

Sketch tracks and trails:

Measurements:

Front length ______ width ________ Hind length ______ width ______
Front length ______ width ________ Hind length ______ width ______
Front length ______ width ________ Hind length ______ width ______
Front length ______ width ________ Hind length ______ width ______
Front length ______ width ________ Hind length ______ width ______
Front length ______ width ________ Hind length ______ width ______
Front length ______ width ________ Hind length ______ width ______

Other Observations

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Module Three: Humans and Winter

Far back in our evolution, humans left the warmer tropical climates of places close to the equator to venture towards the poles. People were met with the challenges of coping with colder temperatures, shorter days, less abundant food sources, and traveling on snowy surfaces. Our ancestors learned to cope with these rigors and develop the means to live in relative comfort without any of the modern gear and technology that we have come to depend on today.

This module explores different topics related to humans and winter. Lesson One looks at the energetics of winter and identifies the different ways that our bodies can lose heat. This is a critical part of learning to stay warm. An experiment with testing the insulative properties of different types of material provides a hands-on demonstration with a practical application for preventing heat loss. Lesson Two examines both traditional and modern types of snow shelters with instructions for students to go outside and create a home for the night. Lesson Three builds on the knowledge gained from Module One and teaches students about avalanches: why they form, how they behave, and how to travel and be safe in avalanche terrain. Lesson Four deals with the first aid topics of cold-related injuries and illnesses, with simulations to identify and treat people with these symptoms. Lesson Five looks at the culture and lifestyle of the Inuit people who are true northern dwellers. Lesson Six explores the fascinating topic of polar expeditions, through historical National Geographic articles as well as interactive web sites that allow students to become part of current expeditions.

Introductory Activity: A Rope-Line to Our Past

To engage students in the topic of Humans and Winter, pull out the climbing rope included in the trunk materials and stretch it out along the classroom floor. Give students the pack of cards which explain the evolution of humans in cold places. You can either divide students into groups, or have them work as a class. Explain that their job is to match the events with the dates along the rope. Sit back and enjoy as the students actively debate and discuss the events on the cards! Use the timeline answers to help guide them.

MATERIALS
Climbing rope with historical dates
Set of Humans and Winter Events cards
Copy of Timeline Answer Guide
Floor space!
Lesson One: Thermal Regulation: Keeping Warm in Cold Places

Background Information

The study of energy is essential to our unit on winter as most physical and biological processes are driven by energy transfers, and a negative energy balance is, in fact, what causes winter. An understanding of the two principle laws of energy is necessary to understand many of the environmental problems that exist, as well as to structure ways of living that are more sustainable. This lesson will focus on the basic principles of the energetics of winter.

The first law of energy states that energy cannot be created nor destroyed, but can be changed from one form to another. The second law of energy states that in every transfer, a significant amount of useable energy (90%) is lost to lower level energy, usually in the form of radiant heat. We saw how this works with the food chain in Winter Predator-Prey. Energy is classified as either kinetic (in motion) or potential (stored) and its forms include radiant, thermal, gravitational, chemical, and electrical. Objects tend towards a resting stage and do so by giving away motion (energy) by touching (conduction) or by sending it off (radiation). Energy travels in waves forming the electromagnetic spectrum, with each wave carrying different amounts of energy. The shorter the wavelength, the greater the energy it carries. Solar radiation is short-wave, while terrestrial radiation is long-wave.

Solar radiation is either absorbed or reflected. About 30% of the sun's radiation is reflected back into space by the earth, atmosphere and clouds. The radiation that gets absorbed by an object is changed into thermal radiation resulting in an increased movement of molecules on the surface of the object. Temperature related directly to thermal energy: the colder something is, the less molecular motion exists. At absolute zero (-273.16 degrees C), all molecular movement stops and the object contains no thermal energy. For our purposes then, all objects have molecular movement and change their thermal energy of their molecules into radiant energy at their surface, sending it elsewhere. In a mercury thermometer, the mercury molecules eventually move at the same rate as what the thermometer is touching, and because colder molecules take up less space in the casing, the reading is lower.

Energy transfers occur by four different methods. Radiation is the movement of energy through a medium without influencing the medium (e.g. feeling the warmth of your hot coffee through your mug). Conduction is the transfer of energy by molecule-to-molecule contact. Convection is the transfer of energy by movement of the medium surrounding an object. Evaporation is the transfer of energy by the change in phase from liquid water to vapor in the air (additional energy is needed to complete the phase change, therefore energy is lost). The direction of energy transfer is always from hot to cold. Under different conditions in winter, any of these four processes may dominate the energy balance of an animal or person. The proper energy balance (net) for earth as a whole is essential for the existence of life.

For both humans and animals, our heat-production is centered mostly in the core of our bodies. Organs, such as the liver, heart, lungs, kidneys, in addition to muscles all help to produce heat. In our extremities, the arms and legs, there isn't enough muscle to produce any heat, nor is there much storage capacity for warmth. Our arms and legs have a large surface area, relative to the volume, and therefore they lose heat rapidly. Heat is moved from the extremities to the core of our body and our brain via blood vessels when we are cold. This survival mechanism enables the most critical parts to stay warm the longest, sacrificing fingers and toes, then arms and legs, first. Whenever we are producing lots of heat, the body sends the excess to the extremities in an ongoing
effort to keep the balance and maintain thermal regulation.

Humans evolved in subtropical settings, and are, therefore, not as well adapted to cold as many other animals. Different individuals, however, perceive winter differently and could even be classified as chionophiles, chioneuphores, or chionophobes. Some of us love it, and some of us hate it! Scientists have worked to calculate the way humans perceive cold. One of the things that we have learned is the effect of wind on our perception of cold. Windchill becomes a common index of how people perceive temperatures as much colder when combined with different speeds of wind. There is a complicated mathematical formula which enables us to state the windchill equivalent temperature (WET) perceived by the human body and reported by the weather announcer. We can refer to a chart, without having to perform the math, and estimate the windchill on any given day.

THE BIG IDEAS

- A negative energy balance is inherent during winter.
- For an organism, compensating for continual loss of heat to the environment is a critical component for winter survival.
- Humans can counteract heat loss to the cold environment through specific survival strategies.

OBJECTIVES

1. To understand the different ways that humans can lose heat from to the environment.
2. To compare these modes of heat loss to one another, and understand which happen faster and could be more dangerous.
3. To compare the insulative properties to different types of clothing.
4. To apply the conclusions learned from the experiments to planning and preparing for a trip outside in winter.

MATERIALS

- Seven containers with lids to hold hot water
- Kettle to boil water
- Fabric patches—denim, cotton, corduroy, wool, heavyweight fleece, lightweight fleece, fur
- Data table
- Journals
- Stopwatch
- Fan

VOCABULARY

Thermal regulation—maintaining the life-sustaining balance of heat gain and loss.
Convection—heat transfer through a moving fluid
Conduction—heat transfer through molecular motion
Radiation—heat loss (propagation of energy) through space
Evaporation
Latent heat of vaporization—the property of water whereby considerable energy is required to change water in skin to vapor
Insulation—property of a material which slows or impedes the transfer of heat energy by
conduction (dead air space most effective, eg. Down feathers, snow)

caution!!
In this experiment, students will be working with boiling water. Be sure that they are supervised
carefully to prevent injury.

PROCEDURE
1. Ask the students to brainstorm all of the different way that they think humans can lose
heat and write their ideas in their journals. Using the handout provided, discuss the
methods of heat loss with them, and provide the appropriate terms to their ideas.
2. Ask students to define the term ‘insulation’ in their journals and provide examples of
materials which they think are good insulators. Then, ask them to list materials that they
think are poor insulators. (The key point for the definition of insulation is the idea of dead
air space. Avoid ‘giving’ students this answer so that they can generate and test their own
inquiries during the experiment. Possible examples of good insulators include down, wool,
fleece, other feathers, straw. Poor insulators might include nylon, cotton, denim, glass,
metal.)
3. Generate questions as a class about the insulative value of different materials.
Facilitate a discussion to reveal what students’ understanding is of how materials insulate
and why some are better than others. In their journals, have students order the following
list in terms of what they predict to be best to worst insulators—
...denim, wool, cotton, lightweight fleece, heavyweight fleece, fur, corduroy... Then, looking
at the four ways that animals can lose heat, predict which would cause the most rapid loss,
and which would be the slowest way to lose heat.
Have students partner up and share their lists.
4. Brainstorm ideas about how to conduct an experiment to test their predictions. The
following is one example of how this might be done.

Inquiry: To compare the insulative properties of different materials.
Procedure: Part ONE
• Fill seven of the same containers with boiling water. Be sure to leave some air space,
then secure the lid tightly.
• Wrap each container with one of the pieces of fabric listed. Place them in a location
with even temperature, such as outside on the snow, away from direct sun.
• Start the timer.
• After 30 minutes, pull the material off and use a thermometer to measure the
temperature of the water inside the container.
• Close the lid, replace the material, and repeat the measurements after another 30
minutes.

- Record the results on a chart.
- REPEAT the experiment with boiling water, recording the temperature at 15 minute intervals, 4 times. Record the results.
- REPEAT the experiment, this time recording the temperature at 20 minute intervals, 3 times. Record the results.
- Average all of the findings.

**NSF CONCEPTS STANDARDS**

**Transfer of Energy**

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.
- The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.
- In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

**Part TWO**

All of the students can conduct each of these experiments to test their own results under the varying conditions, or you can divide students into groups and have each group take on one of these, then compare results with each other.

- Ask the students what the primary mode of heat loss is in this experiment. (Conductive) How would we repeat this test using the other three?
- How could we find out more about the different rates of cooling of the four ways that heat is lost? (Repeat the experiment but manipulate the variables so that different modes of heat loss act on the containers of hot water.
- **Conduction**: Soak each piece of material in water before wrapping the containers.
- **Convection**: Put a fan on to create an even amount of wind across each wrapped container.
- **Radiation**: Place the containers at room temperature, wrapped in the materials
- **Evaporation**: Surround each container with fabric, but leave the lid off and uncovered.

- Compare the results of each of the average rates of cooling for the five different experiments and draw conclusions with respect to (1) the insulative properties of different materials and, (2) a comparison of mode of heat loss on rate of cooling.
ASSIGNMENT
Have students answer the following questions in their journals.
1. Name different ways that a person can lose heat and describe each.
2. If you were to be preparing for spending a period of time in the cold, which type of heat loss would you be most concerned with? Why? Give an example of how you could lose heat this way. (Evaporation—this is the fastest way to lose heat. For example, falling in a cold pond would cause your body temperature to drop very quickly)
3. Which would you be least concerned with? Why? (Radiative cooling—slowest way of losing heat)
4. Based on the experimental findings, list the materials tested in order from best insulators to worst insulators. Compare this with your prediction. How is it similar? How does it differ? Why?
5. What conclusions can you draw from the experiment on heat loss?
6. What does this experiment tell you about preparing for spending time in the cold? List what you would wear, and other things that you would do to keep yourself warm.

FOLLOW UP IDEAS
• Extend this experiment by testing the difference in insulative value of the same materials when they are WET. How might this change your choice of clothing if you are going on an overnight trip during snowfall, or a warm spell?
• Try this experiment with students wearing these different materials to test for insulative value. What are the possible variables that might effect the results? How could you control for these?
• Repeat this experiment to test different materials for waterproofing and/or windproofing. Combining these three activities will provide students with an experiential understanding of how to dress for different weather conditions.
• Encourage students to develop their own experiments to test a question about different modes of heat loss, or insulative properties of different materials. Focus on generating answerable questions, hypotheses, and controlling potential variables.
• Students can make observations of different modes of heat loss using their own bodies. For example, have them compare a wet hand and a dry hand in a wind, with or without wind jackets on a cool, windy day.

OUTDOOR EMERGENCY CARE
Practical Ways of Decreasing Heat Loss
• Wear garments made of proper insulating materials: wool, polypropene, treated polyester, down, Dacron, polyester pile, foam, etc. Avoid cotton.
• Use the layering principle so that you can add clothing to prevent chilling or remove clothing to prevent overheating and excessive sweating.
• Protect yourself from the wind.
• Use adequate coverings for body parts with large surface-to-volume ratio (nose, fingers, etc.)
• Avoid getting wet.
• Avoid direct contact with cold substances.
• Avoid excessive respiratory heat loss.
• Avoid alcohol and nicotine.
*Adapted from National Ski Patrol's Outdoor Emergency Care handbook.
Lesson Two: Snow Shelters

Background Information

Winter recreation has become increasingly popular in places that experience snowfall and cold temperatures. The outdoor gear industry has utilized technology to provide people with the means to travel comfortably over snowy terrain. The mountains around Missoula draw folks from town out on weekends for cross-country skiing, backcountry touring, snowshoeing, snowmobiling and riding lifts in ski areas. For people who want to spend more than a day exploring different areas during the winter months, learning to build cozy and safe shelters to overnight in is a critical skill. This lesson explores a variety of ways of creating modern and more traditional types of shelter for overnight trips.

There are several different types of snow shelters that provide effective protection from the winter elements. Tents can provide shelter from wind and snowfall. There are a variety of brand names and fabrics that tents are now made of. Tents are quick to set up and easy to take down. The downside of using a tent for winter shelter is that it is usually not as warm inside as other types of snow shelters, they are expensive, and it is an added weight in your pack.

Snow Shelters There are a variety of ways of making a home out of snow. All of these require some care, skill, and patience. When constructed correctly, they provide excellent protection from the frigid temperatures outside. Be sure to have extra gloves and other spare clothing, as you will get wet constructing these homes.

Quintzees are a type of shelter constructed from snow, that originated from the Inuit people of northern Canada. To construct a quintzee, you need a shovel. Build a large (10 feet diameter X 5 feet height, approximately) pile of snow, stopping two or three times to stomp it down as you go. This mechanical breakage of the snow crystals contributes to sintering, which helps form bonds between crystals that create stability and structure to your mound. Let the pile settle for an hour or so, then begin to dig out a space inside where you can sleep. The entrance needs to be lower than the sleeping platform to allow the cold air to drain out. Make sure the walls are not thinner than a foot or so. (You can see the light come through if it is getting too thin.) When you are done, use a ski pole to poke two or three air holes in the upper corners.

Igloos These are the traditional homes of Inuit people and require the most skill to build effectively. Blocks are cut out of the hard snow and placed on edge in a circle spiralling upwards and leaning in to form a dome. Wind-packed, level snow is the best material for building. Start on a hardpacked surface and use a snowsaw to dig out the blocks. (You can stomp down a quarry, let it settle, then use that to build your blocks out of.) One person can stand inside to support the blocks as the other person cuts them and hands them in. A good size is around 30X10X3 in. If the snow is softer, you can put a few handfuls between blocks to help 'cement' the wall together. Placing the final block is the trickiest. Measure the shape, and gently put it in place, with support from the inside.

Snow Caves are similar to quintzees as they are dug out; however, they are built within existing terrain features caused by wind. To build one, find a slope that has a pile of snow
or small cornice and begin digging out the center starting from below the overhanging part. The same principle of cold air drainage applies here, so be sure the entrance is below the sleeping platform. Be sure to also include an air vent when you are finished digging out your shelter.

(Refer to diagrams)

**THE BIG IDEAS**

- Different forms of shelter can be built from snow that provide protection from winter and a fun place to spend the night.
- We can learn from traditional methods of living in cold climates that have been developed by people like the Inuit.

**OBJECTIVES**

1. To learn how to build different types of snow shelters.
2. To spend the night outside in winter.
3. To develop self-reliance and the ability to be comfortable under adverse conditions.
4. To appreciate the ingenuity of people who have lived without modern conveniences.

**MATERIALS**

- Shovel
- Snow saw
- Extra clothing
- Optional: overnight camping equipment/clothing

**TIME**

- Shelter building: 3 to 4 hours
- Optional: overnight camping trip

**PROCEDURE**

The best learning experience for students with this lesson is to build different winter shelters and spend a night out in them. This can be done, with permission, near the base of local ski hills before they are open to the public, or out of the way of their daily operations.

**ASSESSMENT**

- Performance-based assessment—After students have built their shelters and spent some time inside them, use a thermometer to measure the air temperature and compare this to the outside air temperature. If the structures have been built effectively, the inside should measure close to zero, regardless of the outside temperature.
Just for interest! On one winter trip I did with students, the air temperature overnight dropped to -22F, inside my tent was -16F, and the snow caves and quintzees were -2F!

- Have your students develop an instructional video to teach other people how to build shelters in the snow.
- Peer mentoring—partner your students up with a younger class and take them outside for an afternoon of shelter building.

FOLLOW UP IDEAS
- Find an experienced outdoors person to go on an overnight winter camping trip with you and your students.
- Build model shelters out of plaster, chicken wire, plywood base OR out of sugar cubes, glue, cardboard.
Lesson Three: Avalanche!

BACKGROUND INFORMATION

Avalanches are a dynamic and fascinating force of nature to study. For anyone playing in mountainous terrain during the winter, they are also a critical phenomena to understand. This lesson builds on Module One to provide a basic overview of some of the principles of avalanche formation, safe travel, and rescue techniques. Even after years of training and study, experts admit that forecasting avalanches is somewhat of a mystery. Nearly all avalanche accidents, however, can be avoided. A basic understanding can open the door to keener observation, lifelong inquiry, and safe travel. Before going into areas where avalanches may occur, it is imperative that you gain more knowledge and skill by taking an avalanche course and spending time with experienced backcountry travelers.

What Is An Avalanche?

Simply put, an avalanche is a fast and powerful movement of snow down a slope. There are two main types of avalanches: loose snow and slab. A loose snow avalanche is also referred to as a point release as it usually starts with a small amount of snow that is not cohesive (loose!) that picks up more snow as it descends the slope. Slab avalanches involve a cohesive layer of snow which breaks away from its support and moves as one unit. The upper boundary is called the crown fracture, the sides are called the flanks, and the pile of debris which forms at the bottom is called the deposition zone. Slab avalanches tend to be the cause of more backcountry accidents because they are typically larger than loose snow avalanches, and the force of that cohesive layer can be greater. We will focus on these in this lesson.

When Do They Happen?

Avalanches usually start due to a trigger such as a skier, a cornice falling, a snowmobiler, or a loud sound. In very unstable conditions, natural avalanches (not triggered by human activities) can be seen. Avalanches can be either wet or dry depending on the moisture content in the snow. The consistency of the slab can also vary. Slab avalanches can slide on a variety of different surfaces; however, rain or sun crusts, and surface or depth hoar tend to be the most common. They can happen at any time of day or night. Weather factors that ought to alert you include:

- Heavy snowfall in a short period of time
- Heavy rain
- Long, cold, clear, calm period followed by heavy precipitation and/or wind
- Rapid warming of temperatures following a storm
- Intense solar radiation
Where Do They Happen?

There are several terrain features which contribute to the likelihood of an avalanche. **Slope angle** is probably the most important, since an avalanche needs gravity to slide. Scientists have learned that slope angles between 25 and 60 degrees are generally the most critical. Less than that and there's not enough pull on the snow, more than that and the snow is constantly sluffing off, so slabs can't build up. The starting zone angle tends to be between 35 and 40 degrees.

The **slope aspect** is another terrain feature worth noting. The direction which the slope faces relative to recent winds and sun can be important. Aspects that have been loaded with snow (leeward) are more likely to develop slabs and cornices which can break off and trigger a slide lower down. Early in the season, aspects which receive the sun's rays can be strengthened, whereas the shaded, colder aspects will maintain weaknesses in the snowpack for longer periods. These north aspects tend to have greater temperature gradients which contribute to depth hoar and more susceptibility to sliding. In the spring, when the solar radiation is more intense, the effect of the sun switches and is more damaging, causing south-facing slopes to be more treacherous.

**Terrain roughness** refers to the surface which the snowpack is built on. The presence of trees, boulders, and shrubs can be helpful as they act as anchors for the snow. Slopes that are smooth and open are more likely to provide a sliding surface.

Finally, the **slope shape** is also an important component of terrain analysis. The stresses are greatest on convex slopes, with fractures tending to happen just below the rollover (where steepness increases on slope). Different types of snow consistency and bonding can cause fractures to happen anywhere that a snow-covered slope is steep enough to slide.

Safety Equipment

People who travel in avalanche terrain need to carry specialized equipment and be proficient at using it. **Avalanche beacons** are expensive and invaluable devices which allow much faster location of a buried victim than otherwise possible. The beacon emits and receives a radio signal that is coordinated with other beacons. When someone is buried, other members of the party switch their beacons to receive and follow the signal which leads to the victim by getting louder as it gets closer. It takes experience and skill to use a beacon effectively. (See the video: Race Against Time, provided in the trunk materials).

What do you do when your signal indicates the person is right below you? You **DIG** with your **avalanche shovel**. Specialized shovels for the purpose of moving snow can be purchased at outdoor gear stores. Some of the features include telescoping handles, wide and sturdy blades, and the ability to take them apart to carry them easily in a backpack. An **avalanche probe** is also an important tool. It is a long, thin pole which can be folded and carried easily. It serves to slide deep into the snow to pinpoint the exact location of a buried person.
**BIG IDEAS**

- Avalanches are a tremendous natural phenomena that have potentially serious consequences for people traveling in the backcountry during winter.
- There is some degree of predictability in avalanche forecasting based on certain scientific principles of force, motion, and triggers.
- Four primary terrain features influence the likelihood of avalanches: slope angle, aspect, terrain roughness, and slope shape.
- Avalanche search and rescue requires the use of specialized equipment.
- Certain weather conditions serve as warnings of increased avalanche danger.

**OBJECTIVES**

1. To gain a sense of appreciation and wonder for avalanches as a powerful force of nature.
2. To learn about what avalanches are, where they happen, weather conditions that influence them, and search and rescue.
3. To gain an appreciation of the skill, knowledge, and experience necessary to travel safely in avalanche terrain.
4. To learn to systematically analyze the factors that contributed to the Crystal Mountain avalanche accident of January 2000.

**MATERIALS**

- Video: Winning the Avalanche Game
- Video: Beating The Odds
- Copy of "Crystal Mountain Avalanche Accident Report"
- Chart paper and pens
- Poster paper and Art supplies

**NSES STANDARDS**

**Motions and Forces**

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

**Risks and Benefits**

- Risk analysis considers the type of hazard and estimates the number of people that might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.
- Students should understand the risks associated with natural hazards.
- Individuals can use a systematic approach to thinking critically about risks and benefits.
VOCABULARY

Avalanche of snow-Rapid, downhill movement of snow.
Aspect-The direction which the terrain is facing (use cardinal directions)
Cornice-The overhanging lip of snow created by wind on the lee side of a ridge.
Deposition Zone-The area in an avalanche path where the debris from the slide comes to rest.
Lee side-The side sheltered and protected from wind; usually where snow gets deposited.
Windward side-The side that gets hit by the wind; often scoured of fresh snow.
Adhesion-The force of attraction between surfaces.
Creep-The slow movement of snow cover due to its plasticity and the pull of gravity.
Crown Fracture-The line of fracture where an avalanche pulls away from the snow that remains on the slope.
Slab-A cohesive unit of snow that can form within or on the snowpack; most common type of dangerous avalanche.
Dust Cloud-The mixture of air and snow particles that accompanies large avalanches.
Trigger-A force or event which triggers an avalanche.

PROCEDURE
1. In their science journals, ask students to brainstorm “What I know/What I think/What I wonder” about avalanches.
2. Encourage them to share their ideas with the class and develop a class chart of questions.
3. Watch the video: Beating The Odds.
4. Revisit the list of questions and solicit answers orally that students picked out from the video.
5. In small groups, ask students to write a list of ways to prevent an avalanche accident. These can then be shared with the class.
6. CASE STUDY
   • In groups of three, ask students to read through the Crystal Mountain Avalanche Accident.
   • Have them list the MISTAKES they feel the skiers made.
   • Beside each point, ask them to write down a better alternative.
   • Debrief the case as a class.

ASSESSMENT
• Provide each student with a piece of poster paper. Tell them that their assignment is going to be to create an advertisement for Avalanche Accident Prevention. Before getting them started, generate a grading rubric. As a class decide on the qualities of an Excellent, Good, Satisfactory, and Fair poster. Once everyone is clear on the criteria for grading, they can go to work on their posters.

FOLLOW UP ACTIVITIES
• Ask a member of the local ski patrol to do a presentation for your class about their avalanche control procedures.
• Contact the local mountaineering club to ask about experienced climbers/skiers who
have witnessed or been caught in avalanches. Invite them to the class to talk about their experiences.

- Research the wide variety of careers related to avalanche forecasting and control.
- Ask an expert to lead the class in a practice beacon search, and a simulated avalanche search and rescue.

References
Lesson Four: Cold-Related Injuries and Illness

BACKGROUND INFORMATION

Learning how to recognize and respond to first aid situations is an important part of becoming a skilled winter traveler. Myths abound with respect to proper ways of treating such cold-related injuries as hypothermia and frostbite. The purpose of this lesson is to provide students with accurate medical information, in addition to giving them the opportunity to practice rescue simulations.

The following is an overview of the signs, symptoms and treatments for the major type of cold-related injuries.

Frostbite

SIGNS AND SYMPTOMS

Frostbite is the freezing of a body part. This occurs when the heat produced by the part, the heat carried to it by the blood, and the insulation covering it are insufficient. The body’s way of protecting the internal organs by restricting blood flow to the extremities when faced with cold tends to increase the chance of frostbite.

The parts of the body that are most vulnerable to frostbite are the hands, feet, ears, cheeks, and nose. These areas are all located away from the heart and have large surface area to volume ratios. In addition, they tend to be more exposed to the elements. Other factors that can contribute to frostbite include inadequate insulation, wet clothing, dehydration, fatigue, poor nutrition, drug use, and smoking.

As skin cools, the following changes can take place:
- blood vessels constrict
- walls of small blood vessels are damaged, plasma leaks into surrounding tissue, causing swelling
- blood circulation impaired in damaged areas
- ice crystals form between the cells
- nerve injury causes pain, then numbness
- clots form in small blood vessels, reducing tissue circulation further
- lack of blood supply eventually leads to tissue death.

Frost Nip

This is the most common and mildest local injury involving cold damage. Internally, there is superficial blood vessel constriction. The skin remains soft and is not actually frozen. The person may feel mild tingling or pain and some numbness. It may appear pale or yellowish. After warming, it will be pink and possibly shiny and swollen. No blisters will form.

Superficial Frostbite

The symptoms of superficial frostbite are a mild tingling or pain, then numbness. Looking at the area, you would likely see gray or yellowish patches of skin. The tissues beneath tend to remain soft and pliable. This type of frostbite is the most common.

Deep Frostbite

Deep frostbite is more serious and involves a full or partial freezing of a body part, usually hands or feet. Deep frostbite should be suspected when a cold body part suddenly stops hurting and is not getting warmer. The part will be cold, solid, wooden, numb, and the skin will look pale and waxy. It looks like a piece of chicken just taken out of the freezer. When the part thaws, it can be classified by degree in terms of severity, similar to burns.
The amount of tissue damage depends on how long the area was frozen, and how cold it was.

**TREATMENT**

Experiments have shown that rapid rewarming results in less damage than slower rewarming of an affected part. The best way to deal with a frostbitten body part is rapid rewarming in a water bath with the temperature carefully controlled around 102 °F. Rewarming should only be done in a sheltered area where the patient can be kept warm. Constricting objects such as rings need to be removed. Continue rewarming until the area turns deep red or bluish (about 20-30 minutes). Keep the patient calm, offer them hot drinks. Rewarming is very painful. The WORST thing to happen after rewarming is for that part to become frozen again. This ALWAYS leads to gangrene. Cover the area with sterile dressings, loose roller gauze, then insulation. Elevate to reduce swelling. Seek medical attention as soon as possible.

**Hypothermia**

**SIGNS AND SYMPTOMS**

Hypothermia refers to the cooling of the body's core temperature below 95 degrees F. The combination of cold, wind, and water is especially dangerous, such as being caught in a blizzard, or falling into a cold, mountain stream. When the body's temperature falls, all of its functions slow down. The initial one to two degree drop results in shivering, then clumsiness, stumbling, falling, difficulty speaking, and confusion. The person is often unaware of what is happening and may deny that anything is wrong. If use of the hands become impaired, it is more difficult to put on clothing or make a fire. Below 90 degrees F, shivering stops and the muscles become progressively more rigid. The breathing and pulse rates slow and the person can lapse into a coma. Death usually results at temperatures below 80 degrees F.

Hypothermia is difficult to recognize in its early stages, but death can occur within as little as two hours of the onset of symptoms. When the body becomes too cold to even shiver, it is necessary to have outside help for warming. It is categorized based on duration of exposure. Acute is less than one hour, subacute is between one and 24 hours, and chronic is more than 24 hours. As time passes, the difference between the core and shell temperatures of the body decreases. The following are some more signs to look for:

- **99-96 degrees F** Intense shivering and impaired ability to perform difficult tasks.
- **95-91 degrees F** Violent shivering and difficulty speaking, sluggish thinking, amnesia.
- **90-86 degrees F** Shivering stops, muscles become rigid, exposed skin is blue or puffy. Movements are jerky.
- **Less than 85** Coma

Suspect hypothermia when a person is shivering, acting clumsy, stumbling, dropping things, slurring speech and lagging behind. Anyone found in the outdoors in winter who is injured, ill, or unresponsive should be treated for hypothermia.

**TREATMENT**

The primary objectives of treating someone with hypothermia are:

1. Prevent further heat loss;
2. Rewarm the patient;
3. Rewarm the body core first, then the extremities, if possible;
4. Treat patient gently.
5. If the patient can swallow, give them fluids.

The first thing is to get the person out of the wind or water, and into some kind of shelter. If the clothing is wet, try to replace it with warm, dry clothing. Cover with blankets, sleeping bag, or other insulation. Think about the different ways that a person loses heat from their body and try to deal with each of those. Insulation from below and above, dry, out of the wind, hat. If possible, build a fire and/or light a stove. Seek medical attention as soon as possible. The fastest method of rewarming would be putting the person in a hot tub, or wrapping in electric blankets. Slow methods include shivering inside a sleeping bag, heating pads, or filling water bottles with hot water and placing in the areas of greatest heat loss.

**Did You KNOW?**
During World War II, 30,000 British sailors died of hypothermia. Napoleon estimated losing 50,000 soldiers from cold. It is also a factor in about one third of the 8,000 drowning deaths every year in the U.S.

**Sample Cold-Weather Survival Kit**

**Shelter-building equipment**
- Plastic or nylon tarp
- Snow shovel
- 50 feet of nylon cord
- Folding saw

**Fire-building equipment**
- Waterproof matches
- Firestarter
- Candle
- Sturdy hunting knife

**Signaling equipment**
- Whistle
- Signal mirror
- Card with ground-to-air signals
- Flashlight
- 35 cents for pay phone

**Optional**
- Thermarest or piece of ensolite
- Small ax
- Stove and fuel
- Snow saw
- Sleeping bag

**Other**
- Compass
- Map
- Metal pot with bale
- First Aid kit
- Toilet paper
- Sunglasses
- Sunburn cream
- Lip salve
- Spare mittens and socks
- Water bottle
BIG IDEAS

- There are certain injuries and illnesses that are related specifically to exposure to a cold environment.
- Knowledge of how to identify symptoms and treat frostbite and hypothermia can improve the likelihood that these conditions go unnoticed.
- Practice of first aid skills with rescue scenarios is critical for understanding how to react in stressful situations.

OBJECTIVES

1. To be able to recognize the signs and symptoms of frostbite and hypothermia.
2. To be familiar with basic treatments for these conditions.
3. To practice rescue simulations for cold weather environments.
4. To learn a system for basic first aid assessment.

MATERIALS

Chart of Basic First Aid Assessment system
Set of First Aid Cards
Simulation Scenarios
Optional: first aid supplies, sleeping bag, hot water bottles

TIME

Part one: 45 minutes
Part two: 1-2 hours

PROCEDURE

Part One: Shakespeare Does Med School (First Aid SKILLS)

1. In a class discussion, ask the students what they know about injuries or illnesses that happen in winter, as a result of being exposed to the cold. Encourage them to describe and name the conditions with which they are familiar. Record these on a chart. Continue by asking them what they know about how to treat these different problems. Listening to their ideas and recording them will give you an idea of what some of their misconceptions may be about these first aid topics.
2. Split students into groups of 3 or 4.
3. Provide each group with one First Aid Card and ask them to read it carefully. In their small groups, give the students a time limit of about 15 minutes and tell them that they need to make up a skit which incorporates the first aid information in a realistic way.
4. Go around to each group and make sure that they understand the illness/injury and how they are going to represent that together.
5. Have each group of students present their skit to the rest of the class, without telling them the condition. When the skit is done, have the audience guess the condition, the signs and symptoms, and the treatment. Record this accurate medical information on a chart for each group. There should be lots of laughing and debate as the audience tries to decipher the skit. The performers can help provide information from their First Aid Card.

6. Once everyone has had a chance to present their skits, there will be a set of charts that represent "What we thought..." and "What we now know..."

Part Two: The Pretend Real Thing (First Aid Simulations)

1. Depending on the size of the class, you can do these simulations as either a whole class or split the group in two. Ask one person to be the patient for each group. Everyone else can leave the area while you review any of the following simulations with the patients. Once the acting person feels ready, have him/her take up a position outside and begin to act out the symptoms described. To make it more challenging for that person, don't identify the condition. You may want to ask the rescue group to choose an acting leader for the simulation ahead of time, or let them figure that out themselves during the rescue. (There is a copy of these simulations in the appendix so you have the choice of reading them out to the class, or giving them a copy of one.)

A. You and some friends are out snowshoeing around in the woods up Patty Canyon. You brought a couple of chocolate bars but no water to drink. A fun game of hide and seek gets you all laughing and rolling around in the snow. Before you know it, it's starting to get dark. You are all pretty covered in snow and as the sweat from your games starts to get cold, someone suggests that you all start to head back to the trailhead. As you are trudging back, one of your friends begins to get mad. Joe says he's freezing, tired of walking, and wants to sit down and rest for awhile. You try to talk him out of it, but by this time, everyone is getting cold and frustrated. A few people keep walking out, while Joe continues to sit in the snow. You notice that he is shivering harder, and starting to slur his words. What do you do?

B. You and some friends are ice skating for the afternoon. A couple of people disappear for awhile, then come back smelling like alcohol. Everyone continues skating while these four make a show of themselves, laughing and falling constantly. One of them is missing gloves, but seems to be oblivious to the cold as she crawls around on the ice. You start to wonder how she could be doing that without getting cold so you decide to go over and ask her if she's o.k. When you get closer, you notice that she's sitting down and two of her fingers are dramatically more white than the others. When you feel them, she says they are numb and that she's fine. What do you do?

C. Your class has gone to the ski hill for a day of lessons. Once the lessons are over, you
are all skiing around in small groups. Some of your friends take off for the trees and you
don't see them for quite awhile. You decide to head over there to take a run and also see if
they are o.k. Eventually you find the group, but they are wondering where Sue is. You know
that she is a very good skier, but she's been missing for awhile and everyone thinks
something bad has happened. What do you do? Eventually you see her jacket and ski over
to find her sitting up against a tree acting out of it, and confused. What do you do?

Basic First Aid Assessment (Responsive patient)
1. Check scene for safety.
2. Introduce yourself.
4. Check for Severe Bleeding
5. Check appearance (skin color, temperature)
6. Ask "What happened?"
7. Call for medical assistance.
8. Keep warm, comfortable, help with minor injuries.

Basic First Aid Assessment (Unresponsive patient)
1. Check scene for safety.
2. Look for mechanism of injury.
3. Yell and pinch for response---if none...
4. Call for medical assistance.
5. Check Airway, Breathing, Circulation.
6. If normal---RECOVERY POSITION, if abnormal----RESCUE BREATHING
7. Keep warm.

ASSESSMENT
1. Have students develop a set of grading criteria for a rescue simulation. They can use the
First Aid Cards to check off the important steps for treatment. Once everyone agrees on
how they will be evaluated, give each pair of students a simulation and have their peers
provide feedback for them.
2. In their science journals, ask students to list the signs and symptoms of the different
stages of both hypothermia and frostbite.
3. Have students write the three most important things that they learned about cold-
related injuries and illnesses. Also ask them what they would still like to know more about
that relates to winter first aid.

FOLLOW UP IDEAS
1. Do lots and lots of simulations. Have students make up their own for each other. The
more practice with basic first aid assessment, as well as cold-related injury symptoms and
treatment, the more confident students will feel.
2. Ask a paramedic or nurse to come visit the class and show more of the medical technology available to help patients with hypothermia and/or frostbite.

3. For particularly keen students, you can have them research other cold-related injuries and illnesses such as AMS (Acute Mountain Sickness), evacuation techniques such as building stretchers, or other advanced first aid topics.

References
Lesson Five: Polar Expeditions

For hundreds of years, exploration of different areas around the earth has been undertaken by curious and adventurous people. Some of the most remote and forbidding places which people have traveled to are the north and south poles. These polar regions are virtually uninhabitable by human beings due to the extreme cold, lack of plant life, excessive winds, and constant exposure. Here, people the role people play is very small, indeed. In this lesson, students will examine various historical expeditions and will conduct research on current adventures via the internet.

Big Ideas
• An essential part of human nature involves the desire to explore new territories and challenge oneself in adventurous situations.
• Polar expeditions have been undertaken on many different occasions with varying results.
• The two poles of the earth are, arguable, some of the last remaining truly wild and relatively unknown places.

Objectives
1. Students will gain an appreciation for the will to survival and ability to endure hardship shown by many people who have undertaken polar expeditions.
2. Students will know more about historical expeditions.
3. Students will use the internet to investigate current expeditions and possibly be involved in ongoing dialogue with explorers.

Procedure
1. Using the articles from the National Geographic magazines, have students read through the major events and develop a timeline for the expeditions.
2. Students can write information at each date, along with pictures of whatever they choose to represent from what they learn about each expedition.
3. As an extension, students can develop biographical outlines of the leaders of each of the major expeditions. Writing detailed information about that person's character traits could lead into an interesting discussion about leadership styles and group decision-making.

Follow Up
• Read "Endurance", a true story about Shackleton's adventure. Ask the students to identify the leadership styles and critical decisions made that led the group into various situations.
• Search the web for addresses of current polar expeditions. Often, explorers will keep daily logs that they post over the internet that students can access.

Materials
• Copy of National Geographic polar expedition articles
• Large pieces of paper
• Felt markers

Time
50 minutes
Appendix

- Handouts for lessons
- Trunk Materials
- Letter to Parents
- Web Sites
- Inuit enrichment materials
- References and resources
Module One: Lesson Two- Task Cards for Copying

Station One: Air Under Pressure
Use the materials provided to design an investigation of the following questions:
• How is air inside the tire tube different from air outside?
• How does the temperature of air differ under different degrees of pressure?
• When in nature is air forced to expand and contract? What happens with the temperature under these different conditions?
Make some hypotheses about how this would influence weather. How could you test your hypotheses?

Station Two: Air Expansion
Fill the jar almost to the top with cooking oil. Tape the tube to the side of the jar after inserting it to within 1/4 inch from the bottom. Blow air bubbles into the tube and observe how they behave. Explore the following questions with your group:
• What happens to the size of the air bubbles?
• Make some hypotheses about why this is happening. How can you test these?
• What role does the oil play in this experiment?
• How does this relate to air rising in the atmosphere? What behaves like the oil to influence air?
• What does this mean in terms of weather? Draw a diagram to illustrate your ideas.
Station Three: The Weight of Air

Use the balloons as containers for air and design an investigation to determine whether air has weight. You can poke a hole through the balloon that releases air slowly if you first put a piece of tape on the surface of the balloon. Discuss the following questions with your group and write your answers on the paper provided.

- Does air have weight? How do you know?
- What other experiences have you had that might provide information about the properties of air?
- If we know that the atmosphere is 370 miles thick and is composed of gases that together we call air, what hypotheses can you make about properties of the atmosphere?

What is air pressure? How might it change with altitude, if at all? How do you know?

Station Four: Convection of Hot and Cold Fluids

Fill a cup with colored hot water and securely cover it. Fill the jar with cold water and design an investigation which demonstrates how the different temperatures of the water interact with one another. Use food coloring so that you can see what is happening to the different temperature fluids. Before performing your experiment, make some predictions and write these on the paper provided. During your investigation, answer the following questions with your group:

- What do you observe happening with the warm and cold fluids?
- What happens to air when it is heated? How do warm and cold air interact with each other?
- What rules do you think that molecules behave according to? Write down three.
- How do warm and cold air interact in the atmosphere? What influence do you think this has on weather? How could you test this?
Module One: Lesson Four: Crystal Metamorphism in The Snowpack

Snowpack Observations

Date__________________________
Location______________________

Air Temperature__________ Surface Temperature ________________

Predictions about general characteristics of snowpack (Temperature Gradient or Equitemperature-why? what do you expect to observe?)

Initial observations (moisture content, evidence of wind, recent weather)
  Surface condition

Snow loading (presence on trees? rocks? piled up in places?)

Foot penetration

Other observations

Digging A Pit
What do you notice while digging?

Layering (identify each major layer, crystal type, approximate depth, temperature)

Stepping Back
How did your predictions match with your observations?

Surprises?
Module Two: Lesson Two- Size Matters (Station ONE)

Student Instructions
1. Imagine that each of these blocks represents an animal. If you were to place each of these creatures out in the cold, which would lose heat faster? Keeping in mind that volume helps determine heat production and surface area determines heat loss, which creature is at a disadvantage due to its size? Why? Write your predictions in your science journal.
2. Determine the area of one face of each of these blocks (length X width).
3. Now calculate the total surface area of each of these blocks (add all of the sides).
4. Calculate the volume of each of these blocks.
5. For surface area:volume ratios, divide the surface area by the volume. Figure this out for each of the blocks.
6. How much more volume does the large block have for generating heat than the small block?
7. How much more surface area does the small block have for losing heat than the large block?
8. Which organism is at an advantage for dealing with winter conditions?
9. Refer back to your predictions and explain what your thinking is about surface area: volume ratios in organisms living in winter environments.
Container A  Container B

Start
Temp.

2 min
Temp

3 min
Temp

4 min
Temp
Module Two: Lesson Five - Animal Tracks

TRACK GUIDE INFORMATION

General Print Characteristics for Mammal Groups
Learning to be a good tracker takes practice and tenacity. Understanding more about the mammals which live near you will also help you to observe and identify a wider variety of clues. Here are some basic guidelines for identifying some of the families which we might see around this area using observations from well-formed prints.

Canids - DOG FAMILY (Domestic dogs, foxes, coyotes, and wolf)
Print:
• Overall shape longer than wide (roughly rectangular)
• Four toes show in track
• Claws normally show (non-retractable), except in foxes
• Front feet larger than hind feet
• Four well-developed toe pads separated from large main pad (one lobe in front, three in back)
Track:
• C-shaped rotary gallop
• 2X trot with hind feet on one side of line of travel

Felids - CAT FAMILY (domestic cats, bobcat, lynx, mountain lion)
Print:
• Overall shape wider than long (appearing round)
• Four toes show in track
• Claws do not show (retractable)
• Front feet larger than hind feet
• Four toe pads well-developed and separated from large plantar pad (two lobes in front, three in back)
Track:
• Characteristic gait is a walk (adapted for short bursts of speed, not long periods of running)
• In snow, hind and fore feet register exactly
• Gallop-rotary
• Jump will show as 3X pattern because one front print is usually hidden under hind print

Lagomorphs - PIKA FAMILY AND RABBIT/HARE FAMILY
PIKAS
Print:
• Indistinct because of hair on the feet
• Five digits present on each foot - first and smallest toe seldom register in print
• Hind foot larger than fore
Track:
• Characteristic gait—jumping

RABBIT/HARE
Print:
• Indistinct because of hair covering bottom of feet
• Five toes present, fifth rarely registers in prints
• Individual toes often do not show
• Hind foot longer than fore foot
• Plantar pads symmetrical and toe pads evenly spaced
• Small and delicate
Track:
• Commonly use diagonal hop
• When walking, heels of hind feet may not register
• Usually found near cover—reluctant to leave safety

Rodents—PORCUPINES, MICE, RATS, POCKET GOPHER, BEAVER, SQUIRREL
Common to all:
• General shape of foot shows five toes on hind foot and four on front
• Common gait is a walk
Distinguishing features:
• Look for relative size
• Look for drag marks to indicate presence of tail
• Toed-in walk indicates porcupine or beaver
• Climbers show trail patterns where front feet are paired and perpendicular to line of travel
• Non-climbers place front feet in line diagonal to direction of travel

Squirrels
• Generally hibernate, not common to see tracks in winter
• All pads may show
• Larger hind feet shows five toes, front show four
• In snow, drag feet and tails

Beaver
• Tail drag will often obliterate all tracks
• Webbing marks often present, along with claws, except second inside toe of hind foot
• Tracks will often lead to water

Pocket Gopher
• Digging claws of front feet extend past toes
• Prints seldom found
• Waddling gait with dragging imprint made by thick tail
• Snow on sides of track appear pushed up, burrowing as it walks

Did You Know?
Pocket Gophers have an external cheek pouch which means that they can place food into these
fur-lined pockets without opening their mouths!

Muskrats
- Tracks often lead to aquatic areas
- May co-habitate with beavers
- Tails leave undulating drag mark between prints because they waddle as they walk

Voles
- Move in diagonal hop
- Walking gait-hind foot oversteps fore foot
- Tail rarely shows in prints
- Construct large nests of grass under the snow
- Weasels preying on voles will overtake nests and line them with the fur of their victims

Porcupines
- Like to feed on cambium layer under bark of trees; leave pieces of bark and scat at base of trees they've been using
- Clear prints show rough texture of bottom of feet
- All toes seldom show
- Tracks characterized by toed-in and short step

Bears—BLACK AND GRIZZLY
Prints:
- Five toes present on each foot
- Non-retractable claws, usually present in prints
- Hind foot larger and distinct from fore foot-has heel, human-like shape
Tracks:
- Common gait is a walk
- Hind foot placed in front of fore foot
- Either tranverse or rotary lope

Mustelids—WEASEL FAMILY (marten, fisher, weasel, wolverine, mink, otter, badger, skunk)
Print:
- Overall shape wider than long
- Hind prints human-like with long, prominent heels, toes appear crowded
- Five toes on fore and hind feet, usually all show in print
- Tends to show 1-3-1 spacing of toes
- Well-developed claws often show
- Foot pad shaped like inverted-V, except in skunks
Track:
- Smaller, faster mustelids show 2X bounding pattern at angle to line of travel
- Larger mustelids show 1-2-1X lobe
Ungulates—DEER FAMILY (deer, elk, moose, caribou)

Print:
- Overall shape like a upside-down heart with two sides—hoof
- Four digits present on each foot, but dew claws often do not register
- Front feet larger than hind feet

Track:
- When moving fast, front feet will splay more than hind
- Common gaits walking and rotary gallop
- Tend to drag front hooves

Other Mammal Signs

Chewings on trees or branches are frequently and easily observed signs of animals. The location of the marking can provide a clue as to the animal’s size.
- 3 inches—voles
- 18 inches—perhaps beaver
- high in tree or under low branch—porcupine
- shoulder height—ungulate

Also look at the width of the individual tooth marking and the direction the teeth moved through the bark.
- Ungulates debark trees by raking lower teeth up the tree trunk.
- Porcupines and beavers chew at almost a right angle to the tree.

Bark Scrapings can indicate antler rubs when ungulates are working to scrape the velvet from their antlers. A section of bark will be missing, with frayed edges and no chew marks.

Tree Markings can include scenting, rubbing, clawing, and chewing and are frequently made by members of the bear or cat family.
- Claw marks high on trunk—bears stretch and claw sides of tree.
- Limbs missing—bears rubbing backs on trees.
- Large sections missing bark—bears may have debarked tree to get at sweet sap.

Twig Browsing is where small twigs have been eaten by rodents or rabbits and hares.
- Rodents often take several bites, whereas hares can sever twig in one chomp. Look for signs at the break in the twig.
- Ungulates leave jagged edges on the branches because they have to tear off the twigs, since they lack upper incisors.
- Winter browsing will leave a higher trim line.

For more detailed information on the life history of animals and species identification, use the tracking cards provided in the trunk, or read through the books listed in the reference section.
Module Two: Lesson Five- Animal Tracks

TRACK OBSERVATION FORM

Date ____________________ Location ____________________

Weather__________________ Habitat ____________________

Surface__________________ Species_____________________

Sketch tracks and trails:

Measurements:

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Front length ______ width ________ Hind length ______ width ______

Other Observations

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________
**QUINTZEE**

This type of shelter was developed by the Athabascan Indians and takes advantage of areas where there is not much snow, and where it is light and fluffy. A quintzee can be constructed on a flat surface. The piling and stomping creates mechanical damage to the crystals (deconstructive metamorphisms) which encourages bonding and structural integrity.

**SNOW CAVE**

To build a snow cave, you need a natural feature such as a small cornice or snow piled on a side slope. It is also a dugout shelter, but takes advantage of the mechanical damage already done by wind and settling.
# TABLE I

## Military Windchill Chart

<table>
<thead>
<tr>
<th>Wind Speed</th>
<th>COOLING POWER OF WIND EXPRESSED AS &quot;EQUIVALENT CHILL TEMPERATURE&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNOTS MPH</td>
<td>TEMPERATURE (°F)</td>
</tr>
</tbody>
</table>

## EQUIVALENT CHILL TEMPERATURE

<table>
<thead>
<tr>
<th>Wind Speed</th>
<th>Little Danger</th>
<th>Increasing Danger (flesh may freeze within 1 minute)</th>
<th>Great Danger (flesh may freeze within 30 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winds above 40 have little additional effect</td>
<td>Danger of freezing exposed flesh for properly clothed person</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7-10 10</td>
<td>30 20 15 10 5 0 -10 -15 -20 -25 -30 -35 -40 -45 -50 -60 -65 -70 -75 -80 -85 -90 -95</td>
</tr>
</tbody>
</table>

DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSON
Trunk Materials

Animal Pelts
- beaver
- muskrat (2)
- mink
- marten
- bobcat
- ermine

Trackin
- 10 sets of laminated tracking booklets
- 1 set of prints (match with pelts)
- 5 plastic tubs for print making

Snow Observation
- 5 crystal cards
- 5 snowpit cards
- 5 crystal magnifying glasses
- 2 slope meters
- 10 thermometers
- 2 avalanche shovels
- 10 rulers
- 1 snow saw

Videos
- Winning the Avalanche Game
- Avalanche Rescue Beacons-A Race Against Time
- The Wild Ones
- Winter Wolf

Books
- Discover Nature In Winter
- Field Guide to Tracking Animals in Winter
- Stokes Guide to Nature in Winter
- In The Snow: Who's Been Here?
- Mountain Animals In Danger
- Snow Watch
- Snow Sense
- Return Of The Wolf
- Tracking and The Art Of Seeing
- The Other Way To Listen

Posters
- Animal Tracks
- Rules for Predator-Prey Game
- Crystal Metamorphism
- SCREW vectors of winter

Winter Predator-Prey Game
- rule poster
- 5 whistles
- 20 bandanas
- shelter, food, water laminated cards (5 each)

Rope
- humans in northern climates timeline activity

First Aid
- 4 laminated scenario cards
- 10 laminated first aid cards
- miscellaneous first aid supplies for practice
Dear Parents:

During the next three weeks, we will be studying a unit about winter in our class. The lessons focus on three different units. The first one is about snow, and we will learn different weather processes that occur in winter, how crystals metamorphose on the ground, ways to classify different crystal types, and the properties of snow.

Our second unit is about animal in winter. We will study pelts and tracks to learn better identification skills. We are going to investigate different ways that animals have become adapted to living in winter environments. Energy, staying warm, habitat, hibernation and torpor are all topics we’ll study.

Finally, we will be finding out more about humans and winter. We’ll learn some practical first aid skills for dealing with hypothermia and frostbite. Avalanches, how they form and how to avoid them, will also be part of these lessons. Ways that humans lose heat to the cold, and how different insulating materials work will also be the topic of some of our experiments.

This entire unit is correlated with curriculum standards, mostly related to science, but also with some language arts and social studies. A big part of what we’ll be doing is coming up with our own questions and finding ways to investigate the answers: just like real scientists do. We hope to use the internet for some of our research, as well as visits from community experts.

We’d love to have you come visit anytime during our studies. If you have photos, swatches of different fabrics, books, weather data, or any other related stuff/information about winter that you’d be willing to loan us we would appreciate it. We’re pretty excited to learn more about this snowy season that takes up so much of our school year!

Sincerely,
Web Sites

Inuit language lessons
www.arctic.ca/LUS/Inuktitut.html

National Snow and Ice Data center
www-nsidc.colorado.edu/

Antarctica Teacher's Guide
//quest.arc.nasa.gov/antarctica/index.html

Antarctica Experience—one person's journal of four months.
//ice.wizard.net/home2.htm

Become penpals with a school in the Arctic
www.arctic.ca/LUS/ArcticLife.htm

Cyberspace Snow and Avalanche Center
www.csac.org

Acorn Naturalists
www.acorngroup.com
RESOURCES AND REFERENCES


Jones, B.F.; A.S. Palincsar; D.S. Ogle; E.G. Carr (Editors). (1987) Strategic Teaching and Learning: Cognitive Instruction in the Content Areas. ASCD, North Central Regional Educational Laboratory; VA.


**Community Resources**

Dan Leonard-trapper/tracking and furs

Lubrecht Experimental Forest-site director-Patty Robarge

Art Wear-Snowbowl Ski Patrol Director