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Winter Ecology

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—Photo by Christopher Dilger

The story of winter survival is a story of adaptation.

by Karl W. Birkeland and James C. Halfpenny

Winter. As the Earth tilts away from the Sun, the level of solar energy reaching us drops, temperatures dip, and in some areas snow begins to fall. We change our behavior in reaction to the cold, snow, and wind by wearing more clothing, pulling our arms tightly around ourselves, and spending more time inside. Animals respond too, by producing thicker coats of fur, balling up tightly when resting or sleeping, and searching for habitats that are warm and protected.

Winter is the perfect opportunity to introduce students to the concepts of ecology—the perfect time to see the interaction of organisms with their environment more clearly. In winter, harsh environmental conditions pose challenges for survival; how an organism is adapted to and interacts with its environment is crucial.

When we think of winter, we usually think of snow, at least in most parts of the Northern Hemisphere. Snow is an excellent insulator. New snow, with a density of about 150 kg/m^3, has a thermal conductivity approximately equal to that of dry wood. In areas free of permafrost, ground beneath snow usually has a temperature not far below 0°C, even when the air temperature is much lower. This insulating effect of snow is significant for both plants and animals: Root systems of plants are kept from freezing, and small animals can survive under the insulating blanket. Snow cover also protects animals from the desiccating and cooling forces of wind.

Snowpacks, or masses of snow, are not homogeneous but layered. During the course of the season, different storms can lay down different densities of snow. Further, the layers metamorphose after deposition. The complex structure of the snowpack is important to organisms living both under the snow and above it.

Metamorphic processes taking place near the ground-snow interface are important for organisms living beneath the snow, in what is called the *subnivean* space. A temperature gradient present between the warmer ground and the slightly cooler snow above it causes water vapor to be produced. The water vapor rises from the ground to the snow and crystallizes to form loosely packed, large crystals near the ground. These loose crystals, known as *depth hoar,* can be burrowed through easily, making life possible for small animals living in the subnivean space.

Seeking microhabitats

Other metamorphic processes taking place at the snow surface facilitate travel of animals living above snow. Large snow crystals carried by the wind break down into smaller sized crystals, which can pack together better. Sun melts surface snow, which subsequently freezes into dense crusts. Finally, equitemperature processes, which operate in the absence of a significant temperature gradient, cause snow crystals to round off, leading to small, tightly packed crystals with bonding between grains. This densifies and strengthens layers of the snowpack. All three processes provide a stronger surface to walk on, but the harder crust may hinder large animals who break through it.

With this overview of snow cover in mind, students can begin to understand both behavioral and morphological adaptations of animals to snow. A major behavioral adaptation is the movement of animals to *microhabitats,* environments with more favorable microclimates. For example, ungulates such as deer, elk, and bighorn sheep favor south-facing slopes where the sun has melted some of the snow cover. There, feeding and travel are easier. These large herbivores also frequent windswept ridges, where

—*Photo by Wolfgang Bayer*

snow has been blown off, for the same reasons.

While larger mammals search for areas with little snow, smaller mammals seek microhabitats in the deeper snowpack. Mice and shrews rely on the insulating value of snow to survive winter conditions. The subnivean environment provides them with protection from the wind, with constant temperatures more moderate than the subzero air, and with loosely bound temperature-gradient crystals, which facilitate burrowing. Because these small mammals are a major food source for carnivores such as coyotes, their survival is closely tied to the rest of the ecosystem. Winters with early cold temperatures and snow cover inadequate for insulation lead to die-off of this important food base and disruption of the upper levels of the food chain.

Another behavioral adaptation animals make in response to snow cover is a change of feeding habits. When ground food sources are covered with snow, moose, for example, switch from grazing to browsing on trees and leaves. Although the animals obtain fewer nutrients from browsing than grazing, the reduced availability of grasses makes the switch necessary. In addition to browsing, moose feed on plants living in creeks that have not frozen over.

A social behavioral adaptation that some organisms make in snow-covered areas is feeding in herds. Ungulates that paw for food, such as deer and mountain sheep, are often found in herds. In herds, there is a greater probability that animals walking around will scuff up more snow and expose more food. In such a situation, more food is available to each animal for the amount of energy expended.

Herds have other advantages in snow. Because herd members also pack snow, which is easier to travel over than loose snow, it is more energy-efficient for animals of the herd to follow one another. Trailing behavior is an excellent adaptation to snow, and animals such as canines and ungulates take advantage of the favorable energetics.

In addition to behavioral adaptations, some animals exhibit morphological adaptations to snow. The fur on hares and weasels and the feathers on ptarmigans, for example, change to white during winter, blending with the snow and making the prey harder for predators to spot. For weasels, this change seems to be genetically controlled: Weasels from northern, snowy areas turn white even when transplanted to warm climates with no snow. Their cue, day length, is the same whether they are in northern or southern locations. Likewise, weasels from warm, snowless, southern climates will stay brown during winter.

Travel is difficult in winter, with its limited food supply and impeding snow cover. Several factors can affect the ease with which animals travel in snow. Snow depth is one factor; snow density is another. Shallow snow, such as that found on windy ridges, means less sinking and easier travel; harder, denser snow, such as that packed by herds, supports more weight and facilitates travel. A third factor is an animal's feet.

Animals are adapted for one of two basic strategies for travel over snow—snowshoes or stilts. Some mammals

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have large feet in proportion to their body mass; such feet act as snowshoes to support animals on the snow. An example is the snowshoe hare. The hare's main predator, the lynx, also has large feet—the lynx's body size is about that of a bobcat, but its feet are as large as a mountain lion's.

Foot-loading indexes

In contrast, ungulates survive in snow despite having feet that do not support their weight on a snowpack. Deer, for example, have long legs, like stilts, which not only help them in speedy escapes from predators but also enable them to move through snow up to two thirds of their chest height before forward motion is severely restricted. Moose are further adapted for this type of travel; their joints are so flexible that they can lift their legs shoulder high. Lifting saves energy because the moose must push less snow around.

The important relationship is the mass of the animal per unit of surface area of its feet. The more mass an animal carries per unit area of its feet, the deeper it is likely to sink and the more energy it will expend in traveling. Thus, for animals of equal mass, smaller feet let them sink into snow, while larger feet let them "float" on the snow.

An animal's mass per unit foot area is called its *foot load*. Comparison of animals' foot loads is possible using a foot-loading index [1], defined by the following simple equation

$$100 - \left(\frac{\text{g of body mass}}{\text{cm}^2 \text{ of foot area}}\right)$$

Index values for various animals are shown in Figure 1. Higher index values indicate more support from the feet.

With Teton Science School students, we conducted some simple experiments to investigate the factors affecting travel through snow. Our experiments would be easily reproducible by your students. We concentrated on foot loading, types of snowpack, the stresses put on snowpack, and the effects these factors have on penetration into snow.

First, we determined foot-loading index values for three of our students on foot, a dog, and one of the students on skis. We measured the surface areas of their feet and the skis with a ruler, then we determined their masses with a scale. From this data, we used the foot-loading equation to find their foot-loading index values: 83, 82, 81, 83, and 93, respectively.

Next, we marked off a study plot in an undisturbed area of snow. One third of the area we left undisturbed, one third we packed lightly while wearing skis, and the remainder we vigorously packed by foot. The area set overnight.

In the morning, we dug pits in the snow to determine how the various amounts of compaction had affected the snow. As we expected, we found that foot-packed snow was much denser and harder than ski-packed or undisturbed snow. The ski-packed snow showed soft lower layers with a hard upper layer, somewhat similar to a wind crust on a snowpack. The undisturbed site was soft throughout.

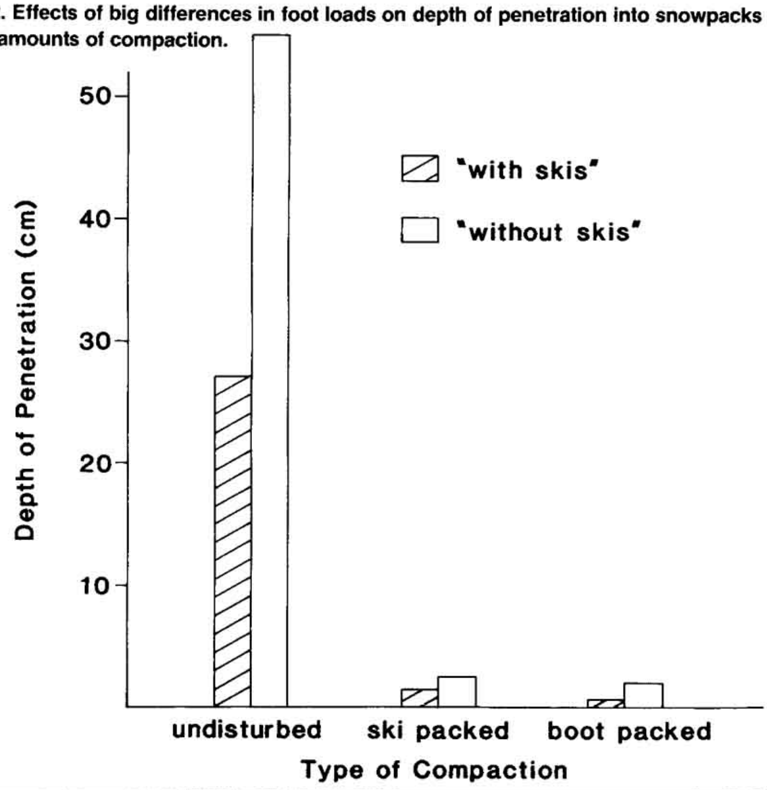
In the afternoon, our test subjects walked and ran over the three areas of snow. Afterwards, we used a ruler to measure depth of foot penetration. On the undisturbed site measuring was difficult because snow sluffed back into the holes. We carefully removed the snow with a glove before taking our measurements.

Not surprisingly, the depth of penetration decreased as foot-loading index value increased. Small differences in foot loads, such as between different people, showed only slight differences in penetration. However, large differences in foot loads, such as those between a person on skis and a

Figure 1. Foot-loading index numbers for various animals.

Organism	Foot-loading index number
Coyote	86
Wolf	85
Caribou	81
Dall sheep	67
Bighorn sheep	64
White-tailed deer	51
Moose	35
Antelope	28
Bison	28

Figure 2. Effects of big differences in foot loads on depth of penetration into snowpacks of varying amounts of compaction.



person without, showed marked differences in penetration. Students can graph the effect of such large differences, as we have in Figure 2, as well as other trends apparent in their data.

The more packed a plot was, the better it supported weight and the shallower the penetration. Students could graph this relationship by determining the density of the snow in the three areas and plotting the densities against the corresponding average penetrations into the snowpack. What about the difference between running and walking? Figure 3 illustrates how running increases the forces put on snow. Your students may discover other trends as well.

Our class made an interesting observation on the difference in walking and running on snow. For this test, three students both walked and ran on the ski-packed site. The upper crust of this snowpack supported our test subjects when they were walking. When they were running, however, two subjects penetrated the crust and sank through the softer snow below. (See Figure 4.) This is a good way to show students how animals can be affected by stresses in their environment.

Figure 3. Effects of walking and running on depth of penetration into snowpacks of varying amounts of compaction. Depths are averages for all test subjects.

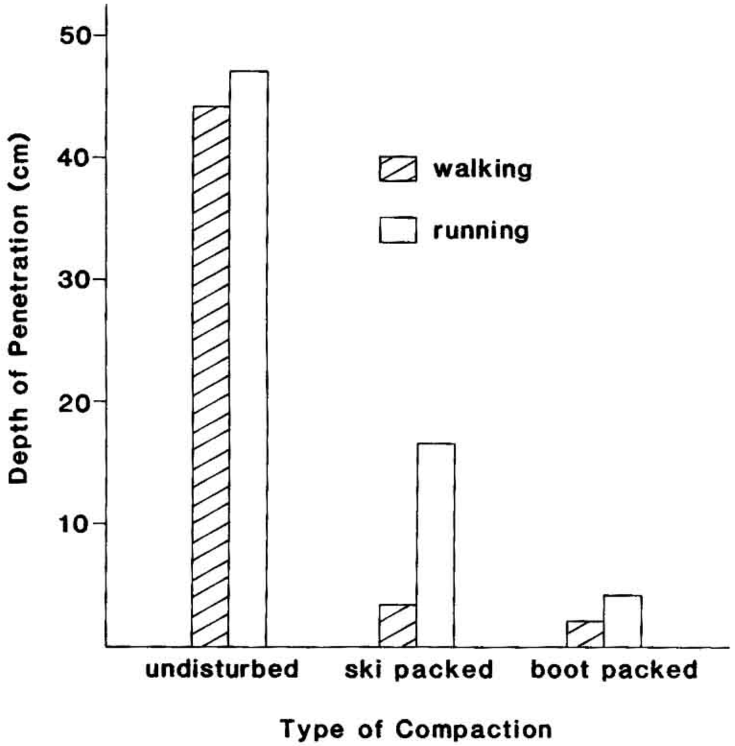
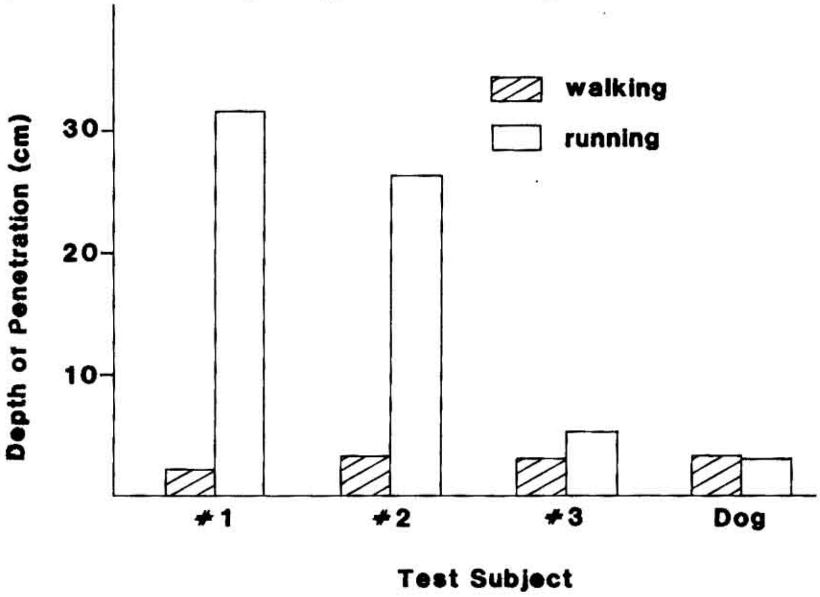


Figure 4. Effects of walking and running over ski-packed snow on depths of penetration. Subjects 1 and 2 broke through the upper crust when running.



Let's say an animal is scared into running by a predator or even by people trying to get a closer look. Its running can increase the force on the snow, increasing penetration. Thus, the animal must use more energy to travel, and it can tire or weaken. The animal may also get stuck in the snow, becoming vulnerable to lighter, smaller predators moving on top of the snow.

The data the students gain in such activities will allow them to predict or explain animal behaviors. Discuss with them how their results demonstrate why some animals live in herds, why many mammals follow one another or search out favorable microhabitats when traveling, and why natural selection has favored an increase in foot size in some mammals living in snowy environments.

To give students an idea of just how advantageous trailing behavior is, you could set up a race. Have a few teams of three or four students race against a single student through undisturbed snow. Group members, who will be able to follow one another while switching leaders, will use considerably less energy than the single runner.

Or, ask students to search for favorable microhabitats. They will have to determine where the snow is shallow, where it is dense, and so on to answer the important question—Where would be the easiest place to travel?

As students think about the challenges of traveling and existing in snow, they will begin to see the interrelationships between organisms and their environments, leading to an understanding of ecology and, perhaps, to a renewed appreciation of their own environment. ■

Reference

1. Tefler, E.S., and J.P. Kelsall. "Adaptation of Some Large North American Mammals for Survival in the Snow." *Ecology*. 65:1828–1834, December 1984.