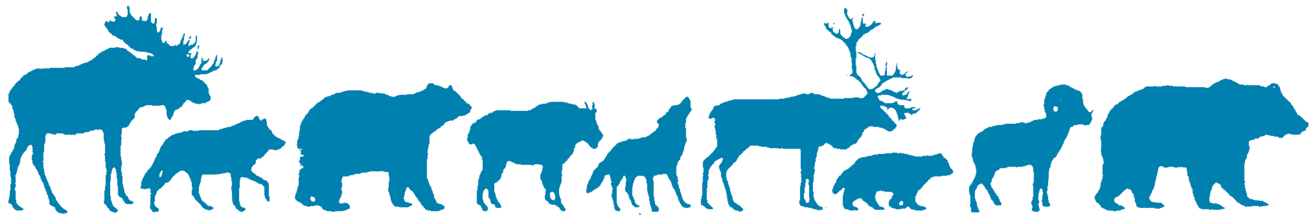


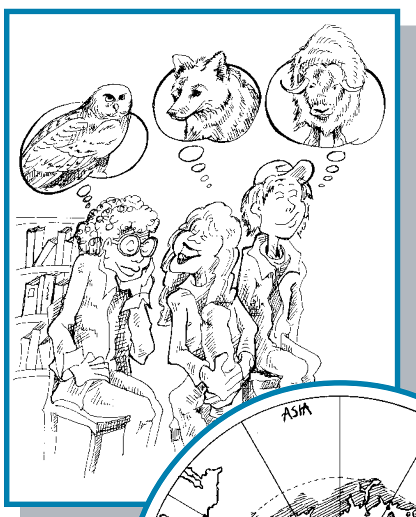
Alaska's Tundra & Wildlife

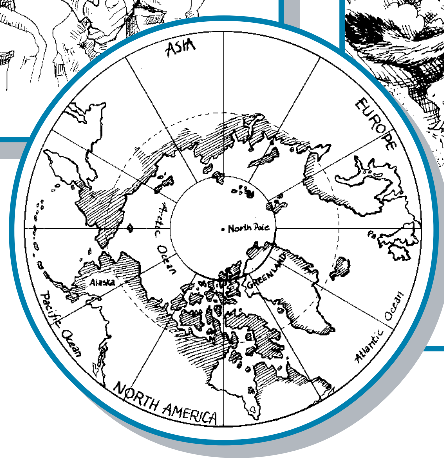
ALASKA WILDLIFE CURRICULUM TEACHER'S GUIDE

K-12

Teacher Background Information, Illustrations, and Resources, Student Activities and Investigation

CORRELATED TO THE NGSS AND STATE STANDARDS





Alaska Department of Fish and Game

Alaska's Tundra & Wildlife

REVISION 2024

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The *Alaska Wildlife Curriculum* is a resource for educators teaching today's youth about Alaska's wildlife. We dedicate this curriculum to you and your students.

ALASKA'S TUNDRA & WILDLIFE is part of the *Alaska Wildlife Curriculum* that includes
Alaska Ecology Cards
Alaska's Ecology & Wildlife
Alaska's Forests & Wildlife
Alaska's Wildlife for the Future

These materials have been field tested in classrooms throughout Alaska. Our thanks to the many teachers, students, and resource agency staff who have worked with and evaluated these materials. Because of your work, these materials are accurate and well used.

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The Alaska Department of Fish and Game has additional information and materials on wildlife conservation education. We revise the *Alaska Wildlife Curriculum* periodically. For information, or to provide comments on this book, please contact us:

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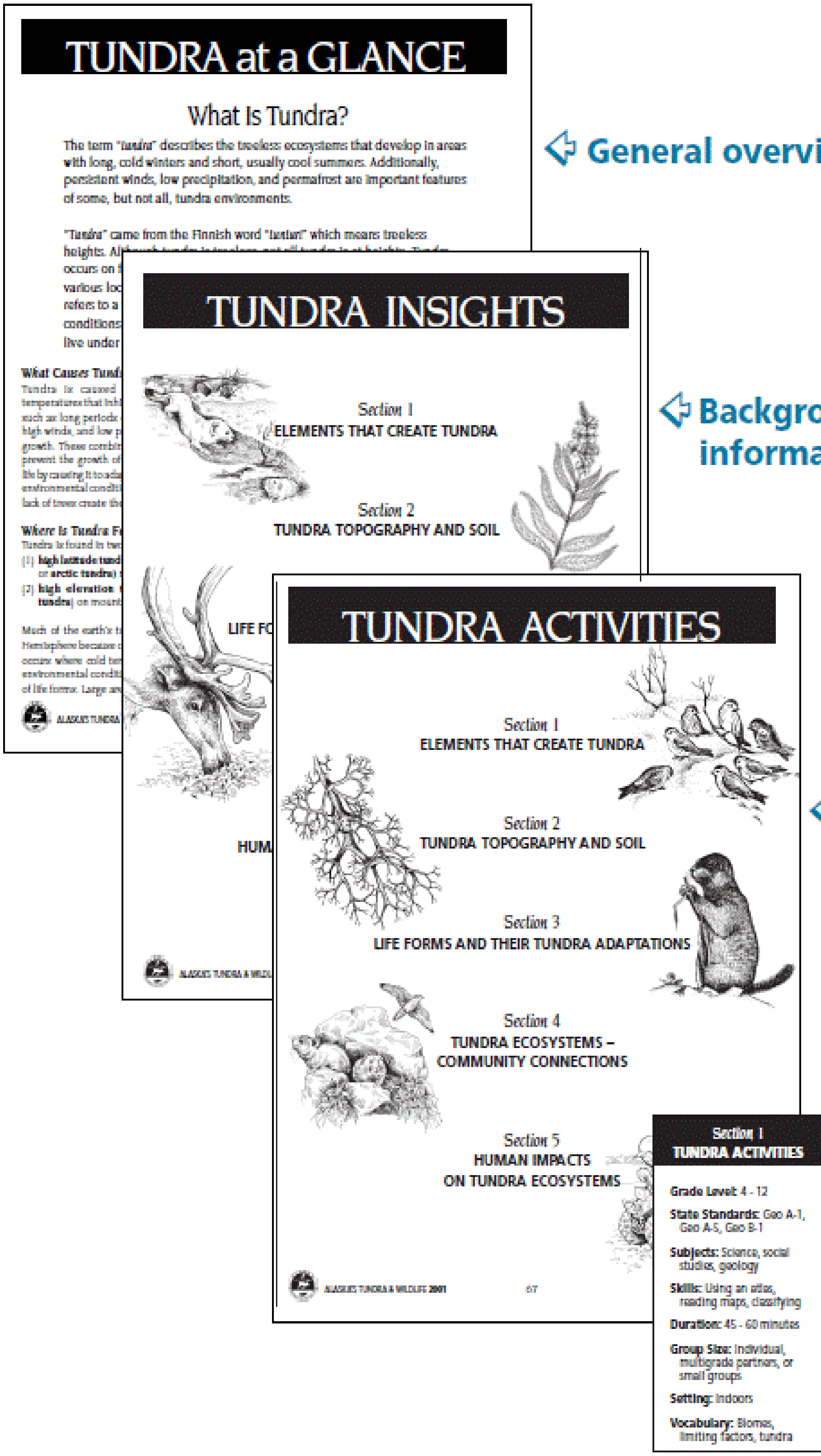
How to use this curriculum



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Student activity boxes provide a quick planning reference

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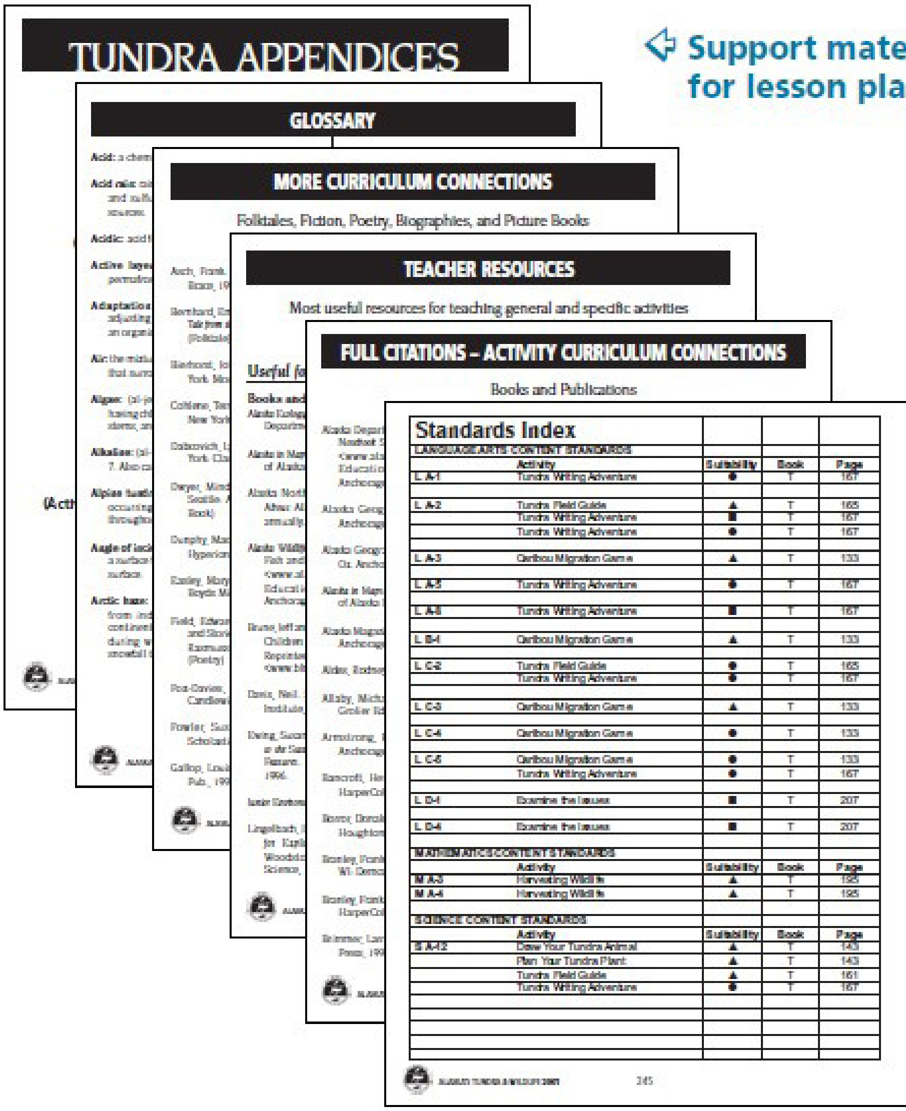
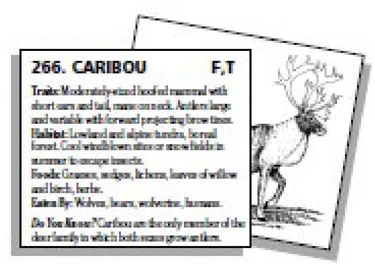


Support materials for lesson planning

ALASKA ECOLOGY CARDS

Alaska Ecology Cards* – Student-directed learning resources in ready-to-copy sheets applicable to all books in the *Alaska Wildlife Curriculum

Several lessons require or may be improved by use of the Alaska Ecology Cards*. To order, contact the* Division of Wildlife Conservation/Wildlife Education.



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Alaska's Tundra & Wildlife

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TUNDRA at a GLANCE

What Is Tundra?

The term *"tundra"* describes the treeless ecosystems that develop in areas with long, cold winters and short, usually cool summers. Additionally, persistent winds, low precipitation, and **permafrost** are important features of some, but not all, tundra environments.

"Tundra" comes from the Finnish word *tunturi,* which means treeless heights. Although tundra is treeless, not all tundra is at heights. Tundra occurs on flat plains, on rolling hills, and on precipitous mountain slopes at various locations around the earth. In the full sense of the word, *tundra* refers to a type of geographic area with characteristic environmental conditions and to the plant and animal communities that have adapted to live under these conditions.

What Causes Tundra?

Tundra is caused by low average ambient temperatures that inhibit plant growth. Other factors such as long periods of low light level or darkness, high winds, and low precipitation also inhibit plant growth. These combined environmental conditions prevent the growth of trees and impact other plant life by requiring it to adapt to survive. The characteristic environmental conditions, specialized plant life, and lack of trees create the ecosystem known as tundra.

Where Is Tundra Found?

Tundra is found in two locations:

(1) **High-latitude tundra** (also called **lowland tundra** or **arctic tundra)** near the poles

(2) **High-elevation tundra** (also called **alpine tundra**) on mountains all over the world

Much of the earth's tundra occurs in the northern hemisphere because of its greater land mass. Tundra occurs where cold temperatures are prevalent and environmental conditions combine to limit survival of life forms. Large areas of high-latitude tundra are found at latitudes greater than 55 to 60 degrees on the coastal plains in the arctic regions of Siberia, northern Europe, Canada, and Alaska.

Alpine tundra can occur at any place in the world where the land's elevation is high enough to experience low average temperatures on a routine basis. Alpine tundra is found in hilly, mountainous, or alpine regions on all continents and can occur at any latitude, including the equator.

What Causes Cold Conditions in Tundra?

Cold conditions found in high latitudes result primarily from the effects of the tilt of the earth's **axis** of **rotation**. Less of the sun's warming energy reaches the surface of the earth in these regions, and lower ambient temperatures occur. High-latitude tundra forms in response to the long, cold winters and short, cool summers found at high latitudes. Secondary effects such as long periods of darkness and persistent high winds produced by large masses of cold air all contribute to the formation of high- latitude tundra.

The cold temperatures that produce alpine tundra are caused by a combination of lower atmospheric temperatures and very rapid heat loss from thin, clear atmospheric conditions. Both alpine and high latitude tundra typically experience persistent winds with the resulting **windchill** factor further reducing the average effective temperature.

Why Don't Trees Grow on Tundra?

Cold temperatures, low sunlight intensity, short growing seasons, high winds, abrasion, lack of moisture, and permafrost are all factors that combine to inhibit tree growth in tundra.

The length of time when growth and activity are possible is very short in tundra environments. Other conditions such as temperature and amount of sunlight are less than optimal for essential plant functions such as **photosynthesis**. Large plants, such as trees, may be unable to survive in tundra environments because they cannot store enough energy and minerals during the short growing season to meet their needs in other seasons.

You don't have to live in the Arctic or Antarctic to be near tundra. Alpine tundra occurs at high elevations all over the world.

In areas with permafrost, the frozen subsurface prevents trees from rooting deep into the soil. Without a strong anchorage, any tree that might grow would be blown over by persistent high winds. Tundra soils underlain by permafrost are very cold. The cold soil inhibits root growth and reduces the ability of the roots to take up water and minerals. Permafrost also traps water near the soil's surface so that poorly drained areas are saturated. Few trees can grow in water-saturated soils.

What Does Tundra Look Like?

Cold, windswept, treeless areas with stunted plant life and vast vistas are features common to both high- latitude and alpine tundra. Frost heaving and either permafrost or shallow rock layers create surface features that give the landscape its relief and its characteristic mosaic pattern.

To escape the persistent winds, plants adapt by growing small and close to the ground. Mosses and lichens are common, giving the tundra a carpeted appearance. Plant growth in protected valleys and water drainages is more luxuriant than that on the often barren exposed ridges.

Arctic tundra typically has many wetlands – ponds, lakes, bogs – that support water-loving aquatic plants and insects. Summer is a time of intensity and abundance. Migratory shorebirds and waterfowl fly thousands of miles to take advantage of this abundance to nest and raise their young. Vast herds of caribou migrate many hundreds of miles from winter refuges near the **tree line** to give birth here and fatten before the next lean season. Resident animals such as lem-mings, voles, weasels, marmots, foxes, and bears have special winter survival adaptations, including for some, **hibernation**.

Do Humans Impact the Tundra?

Most scientists agree that we must be cautious and careful in our use and development of tundra resources. Tracks made by a vehicle 50 years ago are still visible today.

Ecological factors such as slow growth, low productivity, short **food chains**, slow recycling of energy, unstable permafrost soils, and plantsthat are highly sensitive to air pollution are all considerations for any plans for human use. Because tundra wildlife is vulnerable to habitat destruction and overhunting, the public and resource managers must work together to minimize human impacts. Disturbance or damage to the soil impoverishes the food web which may take years to rebound.

In lands where harsh climatic conditions have kept modern human development to a minimum, long-term effects of human activities on tundra wildlife and land are difficult to predict.

TUNDRA INSIGHTS

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ELEMENTS THAT CREATE TUNDRA

Section 2

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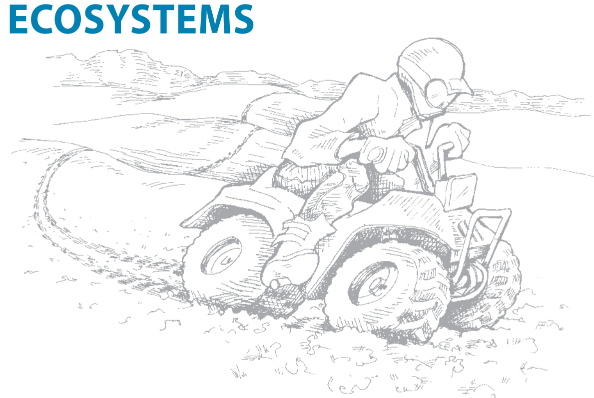
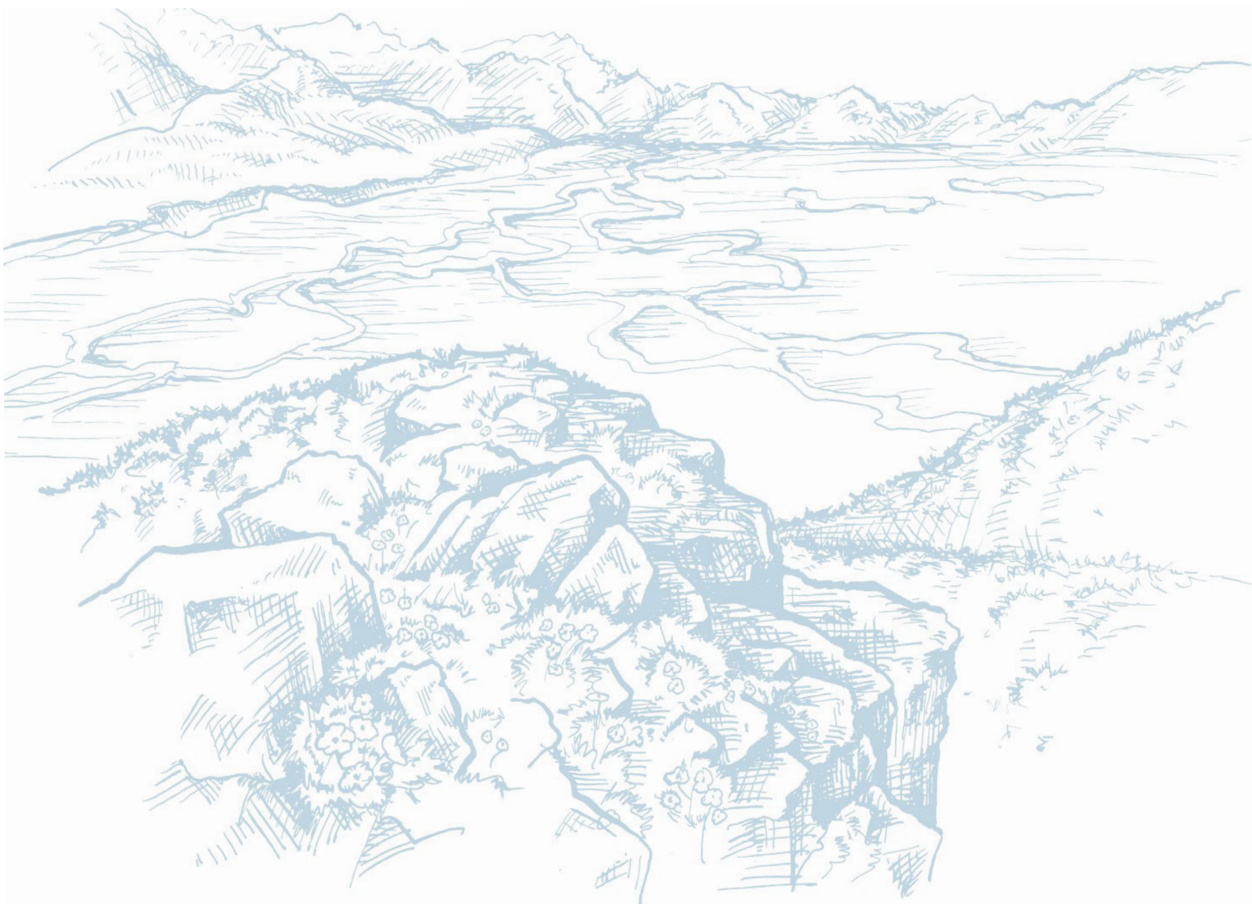
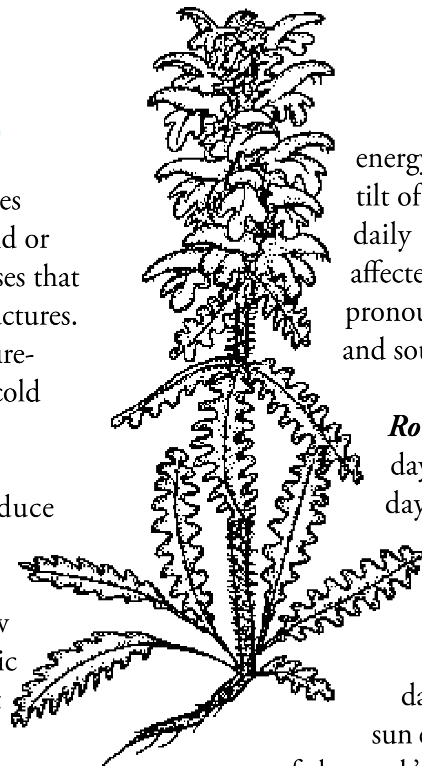




Elements that Create TUNDRA

Section 1
TUNDRA INSIGHTS



TUNDRA TEMPERATURE

Life Needs Warmth: Low temperatures affect all life forms, whether in lowland or alpine tundra. Life is based on processes that use chemical reactions within cell structures. Chemical reaction rates are temperature-dependent and occur more slowly at cold temperatures.

As an example, plants cannot produce food through **photosynthesis** (make sugar from light energy, water, and carbon dioxide) at temperatures below 19.4°F (–7°C). Other plant metabolic processes such as respiration do not occur at temperature much below this point. The low temperatures in tundra environments inhibit plant growth and affect all life functions by slowing or stopping vital chemical processes.

Tilt of the Planet: Cold conditions found in high latitudes are caused primarily by the effects of the tilt of the earth's **axis** of **rotation**. Less of the sun's warming energy reaches the surface of the earth in these regions, resulting in lower **ambient temperatures**. Arctic tundra forms in response to the long, cold winters and short, cool summers found in high latitudes. Secondary effects such as long periods of darkness and persistent high winds produced by masses of cold air contribute to the formation of arctic tundra.

Energy from the sun heats the surface of the earth to temperatures at which life can exist. The amount of energy that reaches the surface and the duration of time that the energy is present determine the temperature. The tilt of the earth's axis changes both of these factors daily and seasonally. Ambient temperatures are affected in the process, and these effects are more pronounced as latitude increases toward the north and south poles.

Rotate into Day, Revolve into Spring: Normal daylight and darkness patterns that occur each day are caused by the earth's rotation about its own axis every 24 hours. The axis of rotation of the earth is tilted at an angle of 23 1/2 degrees to the plane in which the earth revolves around the sun once every 365 days. The **revolution** of the earth around the sun each year creates the seasons because portions of the earth's surface are tilted toward or away from the sun as the orientation changes.

Seasonal effects become the dominant factor at high latitudes because of a combination of the curvature of the earth's surface and the tilt of the axis. For periods of the year when the axis is tilted away from the sun, the sun may not come above the horizon and will remain hidden behind the curvature of the earth. Periods of darkness as long as six months occur. Little or no energy from the sun strikes the surface to warm it; low temperatures result.

Atmospheric Interference: When the axis is tilted toward the sun, the high latitudes are exposed to long periods of daylight. The curvature of the earth's surface and the curved shape of the atmosphere surrounding it, however, play a modifying role. Because it strikes at an angle, the sun's energy must pass through a thicker amount of atmosphere.

More of the energy is absorbed or scattered, and less strikes the surface.

The energy that does reach the earth's surface at high latitudes is spread over a larger area because of the planet's curvature and the shallow angle of strike. The combination of these two effects results in a lower density of energy reaching the surface. Despite the longer daylight hours, high latitudes receive less warming from the sun and thus have cool summer temperatures.

Alpine Differences: Alpine tundra environments occurs at high elevations at all latitudes. The cold temperatures that produce these environments are caused by physical influences different from those producing the cold conditions of high latitudes. These factors also have other side effects that can alter the detailed nature of the alpine tundra ecosystem.

Warm Days: At high elevations, the atmosphere is thin, usually much drier, and often much cleaner. Energy from the sun passing through the high-elevation atmosphere is not reduced by absorption and scattering to the same degree that it is at lower elevations. The intensity of the sun's energy striking the earth's surface is greater, and the warming produced by the absorption of this energy is rapid. When the sun shines, very warm daytime temperatures can occur.

Cold Nights: These same atmospheric conditions that produce significant daytime warming also allow rapid cooling so that night temperatures drop dramatically. Very rapid heat loss occurs when the energy absorbed during the day is radiated back into space at night.

The temperature of the earth's atmosphere is also colder at high elevations. The combination of rapid heat loss and lower air temperatures causes the nighttime temperatures at high elevations to fall well below freezing.

Latitude Also Affects Alpine Temperatures: Alpine tundra typically experiences a wide variation in temperature over a 24-hour period. Depending on the latitude, alpine tundra may also experience seasonal cold patterns. The higher the latitude, the more pronounced the seasonal effects. During the winter, the seasonal effects may dominate over the daily cycle at high latitudes. Near the equator, the seasonal effects disappear, and the daily cycle is dominant at all times.

TUNDRA SUNLIGHT

Sunlight and Life: A significant part of the sun's energy that reaches the surface of the earth is in the visible portion of the energy spectrum. Sunlight makes a double contribution to life on earth. In addition to warming the environment to a degree at which life can occur, sunlight is vital in the **photosynthesis** process that allows plants to produce the food that serves as the foundation for all other life.

Plant cells absorb **photons** of sunlight. The energy contained in the photons is used by the cells to restructure chemical bonds and manufacture food sugars from mineral nutrients and water in the soil and from carbon dioxide in the air.

In Utqiagvik, Alaska, the sun stays above the horizon from about May 1 to August 2, for 84 days of daylight. In winter, the sun setson about November 18 and rises again on January 24, for 67 days of darkness.

Winter Dormancy: The long periods of seasonal darkness in high-latitude tundra environments prevent plant growth during much of the year: temperatures are too low, and no sunlight is available to conduct photosynthesis.

Summer Growth Surge: The long hours of sunlight present during the summer stimulate plant growth. As an adaptation, high-latitude plants grow more rapidly in order to complete their cycle in the few months available.

The higher the latitude, however, the more moderated the benefit of the extended daylight. Temperatures decrease and lower energy densities of sunlight reach the plants. The most hardy tundra plants, however, are adapted to photosynthesize at low temperatures and low light intensities.

WIND

Movement of Air Masses: Persistent winds are a common feature of most tundra environments. Winds are the movement of air masses from one place to another. Air movement is caused by differences in air density that are in turn caused by differences in air temperature. Cold air is more dense and sinks. Warm air is less dense and rises.

Cold, dense air prevalent in tundra environments constantly attempts to move to warmer, less dense areas. Over arctic tundra, the motion can be driven by large-scale regional weather patterns or something as localized as cold air over the ice pack moving inland after daytime warming has increased the air temperature over the land's surface.

Air movement above alpine tundra generally occurs because cold, dense air at the higher elevation sinks into surrounding lower elevations where the air temperature is warmer. Gusty conditions are common.

Winds Inhibit Tundra Life in Three Ways: This applies to both arctic and alpine tundra environments.

(1) **Cooling.** Life functions are temperature- dependent processes that are impacted by loss of heat to the surrounding environment. Heat loss is counterbalanced by heat absorbed or generated within the organism. Because this balance is dynamic, plants and animals are subject to **windchill** effects instead of simply to ambient temperatures. Windchill creates a lower effective temperature because air moving across a surface removes more heat energy than does still air. The faster the wind speed (up to about 40 miles per hour), the more energy is removed. Persistent winds lower the effective temperature of tundra environments.

(2) **Drying.** Wind increases evaporation and can dry or desiccate leaves and other living tissues. Living cells and tissues of most plants and animals die if dried. Even in tundra areas, where the occurrence and strength of winds are similar to those of mild environments, the cooling and drying effects of wind are intensified because of the absence of trees to block the wind.

(3) **Scouring.** Tissues of most plants, fungi, or other living things are easily damaged by constant scouring of windblown materials. Wind carries particles of dust, ice, and snow that cut and wear down any object in its path. Every winter, anything that sticks up above the snow is soon cut and worn by the abrasion of ice crystals. During the summer, sand and rock particles can cause the same damage to exposed plant life.

PERMAFROST

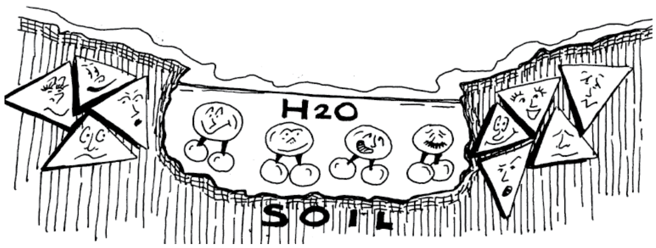
Permafrost (perennially frozen ground) is most common in areas with a mean annual soil temperature less than 27°F (–3°C). Locally, on south-facing slopes or in areas of good drainage, no permafrost may exist. Little permafrost exists in alpine tundra. Instead, rock layers near the surface act as barriers to drainage and restrict root systems.

Alaska Distribution: Permafrost occurs under 85 percent of Alaska's surface area. In northern Alaska, permafrost underlies all lowland tundra areas (except large lakes and rivers). In western and southwestern Alaska, and in the Alaska Range, it is discontinuous (patchy). In the Aleutian Islands and on mountain tops at more southern latitudes, permafrost is absent or rare. Seasonal or nocturnal frost occurs in all tundra soils, however.

When present, permafrost and seasonal frost play an important part in shaping tundra lands and ecosystems. The effects of permafrost in tundra topography are discussed in *INSIGHTS Section 2*.

Flood Influence: The barrier of frozen ground prevents the downward percolation of water. Flooding is common, especially at spring breakup when meltwater has no where to go and overflows river banks, covering the land.

Permafrost Inhibits Growth: Only a shallow layer of soil thaws each summer, dictating that plant root systems also must be shallow. Permafrost chills even the thawed soil and keeps the root portion of a plant's environment comparatively cold, inhibiting growth or requiring special adaptations [see *INSIGHTS Section 3*]. Nutrient uptake and gas exchange processes occurring at the roots are slowed by the lower temperatures.



Retards Decomposition: The icy chill also retards the rate of decomposition in the tundra compared to that in more temperate environments, limiting soil building and the recycling of nutrients. Bacteria and fungi, the main **detritivores** in tundra ecosystems, slow down or become **dormant** in freezing temperatures.

Peat Formation: Because of slow decompositions rates, dead organic material accumulates faster than it can be recycled in lowland tundra ecosystems. Centuries of accumulation of this waterlogged, partially decomposed organic matter form **peat** at a rate of about one meter per 1000 years. Peat bogs are a potential source of nutrients and soil that will remain locked away until a climate change or erosion exposes it.

TUNDRA PRECIPITATION

Life depends on the availability of water in the liquid state. It is an essential requirement for both plant and animal life. The availability of this critical substance in tundra environments can vary dramatically.

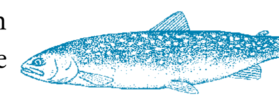
Cold Deserts: Tundra regions in the high latitudes have been called "*cold deserts*" because the amount of precipitation is less than that in many warm region deserts. Subfreezing temperatures lock up much of the water in ice and snow for extended periods. **Desiccation** and dehydration due to lack of adequate water can be important issues in Arctic tundra.

Tundra regions in the far north have been called "cold deserts" because the amount of precipitation is less than that in many deserts – less that five inches (12.7 centimeters) per year.

Alpine Variations: Precipitation in alpine tundra is usually greater than in arctic tundra, but the rapid runoff caused by rocky substrate and steep mountain slopes gives the two areas similar soil-moisture characteristics.

Safety for Birds: If tundra ponds or lakes dry out too early in the summer, birds that chose the safety of islands for nesting will be vulnerable to predation. Similarly, adult waterfowl may have to walk their broods miles to reach adequate water for safe raising of the young. Birds that nest near reliable water bodies have the best chance for successfully reproducing.

Fish Habitat? What looks like a good stream habitat for fish often dries to a beaded necklace of ponds by midsummer. Fish in tundra environments are limited to the few all-season reliable water sources. In winter, the oxygen content of a stream can be used up or a lake can freeze to the bottom, both causing fish die- offs.



Snow: Precipitation in both arctic and alpine tundra primarily comes in the form of snow, although its water content is low. Snow has great insulating qualities that help life survive in a severe environment. By its protective drifts or by its abrasive scouring of exposed ridges, snow helps to shape vegetation patterns.

Deep snow cover also significantly reduces the amount of sunlight reaching buried plants in arctic and alpine tundra. In effect, snow cover extends the period of darkness and reduces the time available for photosynthesis (see *INSIGHTS Section 3* for plant adaptations).

Snow Blanket Retains Earth's Heat

Snow is a good **insulator** because air is trapped in between **snow crystals**. The trapped **air,** a poor **conductor** of **heat energy**, insulates the ground from winter temperatures.

When snow falls in autumn, it covers ground or soil that has stored heat energy over the summer. Without additional input of radiant energy from the sun, the ground cools gradually, but **uncompacted** snow acts as an insulating blanket and traps some of the heat given up by the ground. As a result, the ground stays warmer than winter air, remaining close to 32°F (0°C) – as long as there is a sufficient covering of snow. The ground cools, or gives up heat energy, relatively slowly as winter progresses.

Many tundra animals are **subnivian** and remain active under the snow. Voles, shrews, lemmings, and mice burrow under the snow and dig runways between feeding and resting sites. Ptarmigan and grouse fold their wings and dive into loose snow for protection from cold and predators.

Some dormant insects rely on the insulating properties of snow to protect them from cold and wind. Insect eggs, cocoons, and adults find shelter under vegetation and in the soil.

Snow Characteristics Change

Snow changes after it falls on the earth. Some changes can be described as **constructive snow metamorphism** or as **compaction** caused by outside impacts. Because these changes affect construction by humans, avalanche danger to humans, and shelters of animals, the study of snow receives attention from scientists and engineers.

Constructive snow metamorphism includes natural changes in the layers of snow as new snow falls or as temperatures increase or decrease. Compaction by outside impacts includes such effects as animals walking on snow or vehicles driving on snow. The changes in the snow are shown in the way the snow crystal structures are altered, in the volume of water and air in the snow, and in the temperature of the snow.

One measure in the study of fallen snow is the **temperature gradient** of the layers, from the warmer ground level to the exposed surface.

If the snow layer has a steep temperature gradient, snow crystals change. Snow crystals near the ground lose water vapor through **sublimation** (the water becomes a vapor without going through a liquid stage). Water vapor travels upward in the snowpack. The snow near the ground forms large, cup-shaped crystals called **depth hoar**. The loose consistency of depth hoar is sometimes described as "corn flakes."

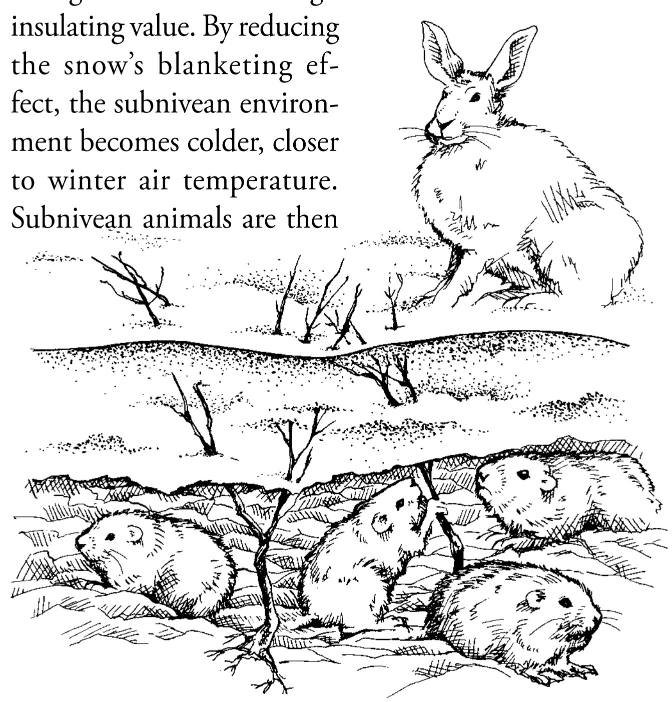
Winter-active subnivean mammals such as voles, lemmings, shrews, and weasels can easily tunnel without hindrance through the loose, weakly bonded snow crystals and can build their winter homes. Large mammals also seek this loose snow to uncover edible plants.

Subnivean animals can be affected by the amount of compaction of snow in several ways:

(1) *Compaction decreases the thickness of the snow pack, thereby increasing the temperature gradient.*
If the compaction is not too extreme, or if it is only brief, the increased temperature gradient develops more depth hoar, which increases the ease of movement of subnivean animals.

If the compaction is extreme, the flakelike depth hoar layer is crushed, and a hard ice layer may develop next to the ground. Hard ice layers are barriers to the movement of subnivean animals. Extreme compaction can be caused by frequent traffic of cars, snow machines, or skis.

(2) *Compaction decreases the thickness of the snow layer thereby decreasing its **insulating ability**.*
Compaction crushes the air pockets between snow crystals that give snow such a high insulating value. By reducing the snow's blanketing effect, the subnivean environment becomes colder, closer to winter air temperature. Subnivean animals are then



forced to use more of their own energy to keep warm.

(3) *Compacted vehicle and ski trails create hard snow "fences" that block travel by subnivean animals.*
Under frequently used vehicle or ski tracks, the compacted snow prevents the development of a depth hoar layer next to the ground. Active subnivean animals need the loose depth hoar for traveling under the snow. If there is plenty of other habitat or depth hoar nearby, the compaction may not significantly change the activity of subnivean life. But it can fence them out of an important shelter or food sources or crowd them into smaller areas.

TUNDRA Topography and Soil

MYTH: Tundra, especially of high latitudes, is flat and featureless.

FACT: Anyone who attempts to walk across tundra soon finds that flatness is an illusion. The land surface is gouged by ravines, gullies, troughs, and sinks and pockmarked by rises, hillocks, and mounds.

Section 2
TUNDRA INSIGHTS

Pingos, **thermokarsts**, **ice wedges**, **frost boils**, and **high and low center polygons** are all landscape features created by **permafrost;** they can grow or change over a span of years instead of over the centuries or a millennium required in other environments *(see following pages)*.

In **high-latitude tundra**, permafrost – perennially frozen ground – lies a few inches to a few feet below the soil surface and can extend to depths of 2240 feet (683 meters).

In **alpine tundra**, where permafrost is absent or patchy, the shallow bedrock or layers of rock near the soil's surface block water drainage and create some of the same landscape features that permafrost does.

TUNDRA WETLANDS

Although precipitation in arctic tundra is similar to that of deserts (5 inches –12.7 centimeters – or less), the water has nowhere to go once it hits the permafrost. The soil above the permafrost or bedrock, called the **active layer**, becomes saturated like a wet sponge. The results are (1) **wetlands** typical of much wetter environments and (2) freeze-thaw landforms of tundra topography.

The tundra contains ponds, lakes, bogs, marshes, and river and stream corridor wetlands. *(For curriculum materials on Alaska's wetlands, see the U.S. Fish & Wildlife Service's* Wetlands and Wildlife.*)*

Mosaic of Wet and Moist Sites

Tundra is a mosaic of many landforms and plant communities. Elevation, which affects the degree of wetness of an area, is an important factor in determining where various plants can grow. Mere inches of elevation can separate different plant communities.

The wettest tundra areas typically have shallow, standing water throughout the summer. Sedges such as cottongrass thrive there. In somewhat drier patches (gravel bars, river banks, hummocks, and ridges of polygons), where surface water drains by late summer, grasses and dwarf willows can become established. The tiny flowers of mountain avens (*Dryas* species), saxifrages, and taller arctic poppies grow there.

Where conditions are dry enough for tussock-forming plants to grow, these plants create their own mini-uplands.

Although initially only several inches higher than the surrounding wet tundra, the tussocks provide roothold for dwarf and shrub birches, Labrador tea, lichens, and berry-producing plants such as lingonberrry, cloudberry, and bearberry.

Migratory Bird Mecca

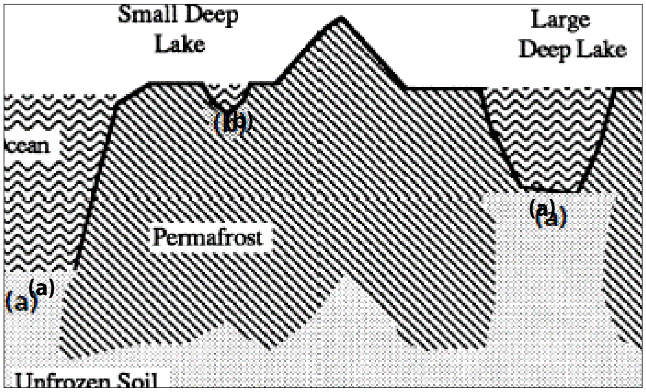
Some tundra wetland areas are extremely productive during the brief arctic summer. Millions of migratory shorebirds, waterfowl, and other birds are attracted to the rich food sources of tundra wetlands for nesting and raising their young. Deep and shallow tundra ponds, lakes, streams, and coastal wetlands are most heavily used *(*see INSIGHTS *Section 3* on migration as a tundra adaptation*).*

Fish Habitat and Predators

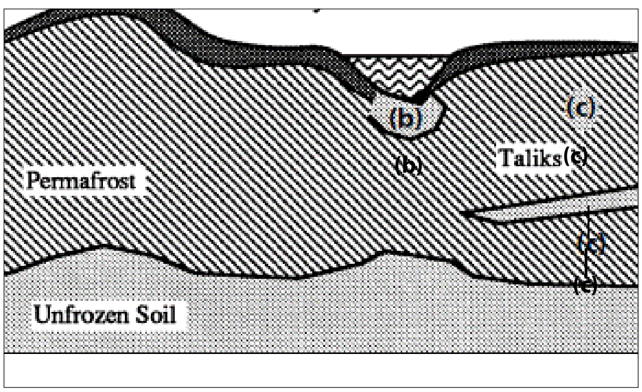
Fish and invertebrates move into flooded wetlands near stream courses, where they grow and reproduce. Sticklebacks swarm in wetland complexes, where they are preyed upon by loons and other fish-eating birds.

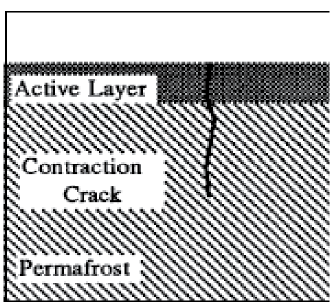
Caribou Calving and Wildlife of All Sizes

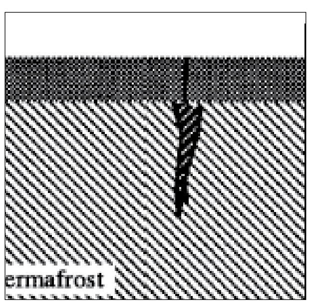
Caribou calve and find summer foods that will allow them to survive the long, lean winter. They seek insect relief on the snowfields that last late into summer. Lemmings graze green growth and stockpile "haystacks" for winter eating under the snow. Brown bears, arctic foxes, jaegers, and snowy owls roam the tundra searching for meals of small mammals or bird eggs and nestlings.



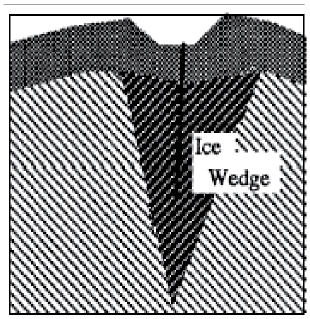
The occurrence and depth of permafrost is affected by the presence of deep lakes, hills, and the ocean. (a) Permafrost is absent beneath large, deep lakes and most ocean areas. (b) Small, deep lakes are underlain by a bulb of unfrozen soil.







Ice wedges are formed when water drains into a contraction crack in the soil, followed by winter freezing and expansion. The ice wedge grows larger each year, forcing surrounding soil out and upward.



Permafrost

Permafrost is perennially frozen ground or ground in which a temperature less than 32°F (0°C) has existed continuously for two or more years. Permafrost may contain chunks of ice or have little or no ice. The upper surface of permafrost is called the permafrost table. Almost no water can penetrate this table, thus it acts as a barrier to water movement (percolation) through the ground.

Continuous permafrost underlies the tundra of arctic and northwestern Alaska. In these regions, the ground is frozen everywhere except under those lakes and rivers that do not freeze solid in winter. Permafrost can extend to 2240 feet (683 meters) below the soil surface. Below this, heat from the earth's core keeps the ground thawed.

Discontinuous permafrost underlies the tundra and forests of interior and southwestern Alaska. In these regions, the ground is perennially frozen in some places, but is free of permafrost in others. Permafrost may not be present beneath south-facing slopes, at sites where vegetation has been disturbed, and under lakes and rivers.

Active Layer

The **active layer** is the surface layer of soil that thaws and refreezes every year. It usually is underlain by permafrost soil. The depth of the active layer varies from about 12 inches (30 centimeters) to 10 feet (3 meters) depending upon the local climate. Near Barrow, the active layer is about 12 inches (30 centimeters) deep.

Talik

Layers and pockets of unfrozen soil that occur within permafrost soil are called **taliks** – *(c) on the adjacent diagram.*

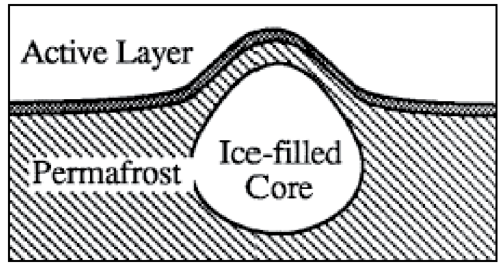
Ice Wedges

Soil contracts or shrinks during periods of intense winter cold. As the soil contracts, cracks form. Often, the cracking makes a loud sound. The winter that it first forms, a contraction crack is small – only 3/8 inch (9-10 millimeters) wide.

During spring snowmelt and summer rains, water flows into the crack and is trapped and frozen by surrounding permafrost. Freezing water expands and forces the surrounding soil upward and outward.

Over many years, the crack gradually enlarges through the freezing and expansion of trapped water and repeated winter cracking. Ice wedges grow to be as much as 33 feet (10 meters) across, and may extend 33 feet (10 meters) below the surface. Some large ice wedges may have taken 1000 years to form. Together, the cracks usually form a polygon (a many-sided geometric shape).

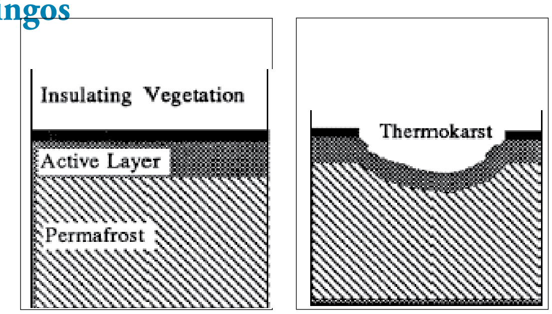
TUNDRA FACTS – PERMAFROST



Thermokarst Dynamics

Water expands as it freezes. Thus, when permafrost melts, the melted water in the soil takes up much less room than it did when frozen. The land slumps into the void, creating a surface depression or **thermokarst**. These thermokarsts may be pits, funnel-shaped sinkholes, valleys, ravines, or, in early stages of melting, caves. Permafrost melts when vegetation is removed (by fire or human activities), the area floods, or the climate warms *(see following article: "Ups and Downs of Life on Frozen Ground").*

Pingos



Thermokarst develops when insulating vegetation is removed.

The word *"pingo"* comes from an Inupiaq name for a cone-shaped hill or mound of soil with a core of ice. An average **pingo** is about 100 feet (30 meters) high and 1650 feet (50 meters) in diameter. Pingos occur in areas of both continuous and discontinuous permafrost.

Closed-system pingos are the most common type in tundra areas. They form after drainage or after sedimentation fills in a tundra lake.

The wet soil underlying a deep tundra lake remains unfrozen year-round because the overlying water retains heat and insulates the soil during winter. When a lake is drained, however, or when it fills partially with sediments so that the water is no longer deep, the surface layer of soil on the lake bottom slowly freezes.

This newly frozen surface and the surrounding permafrost trap water in the underlying, but still unfrozen, soil. As permafrost slowly advances around the trapped, unfrozen core, the water in the soil is forced inward by pressure through soil pores.

When the trapped water itself freezes, it expands in the only direction possible – upward. This creates a hill or mound. The size of the pingo depends on the amount of trapped water. Pingos form and grow by as much as 5 feet (1.5 meters) per year, and continue to grow slowly (1 to $1^{1}/_{2}$ feet [0.3-0.5 meters] per year) for thousands of years.

If vegetation on top of a pingo is disturbed or if pressure from the expanding ice cracks the surface soil, the ice core is exposed to air and warm summer temperatures. When the exposed ice melts, the top of the pingo collapses, creating a crater. The crater may or may not contain a lake.

Polygons

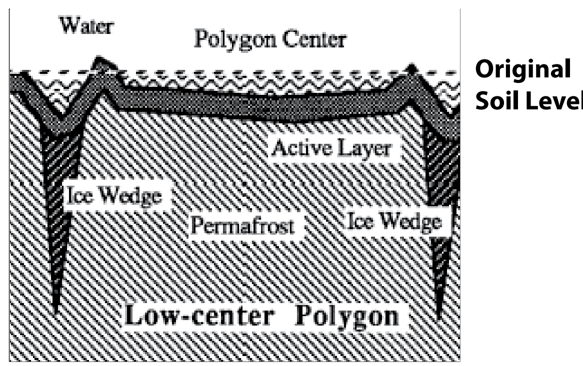
Polygons are a common topographic feature in areas with permafrost and seasonal frost. They are formed by contraction cracks enlarged by ice wedges.

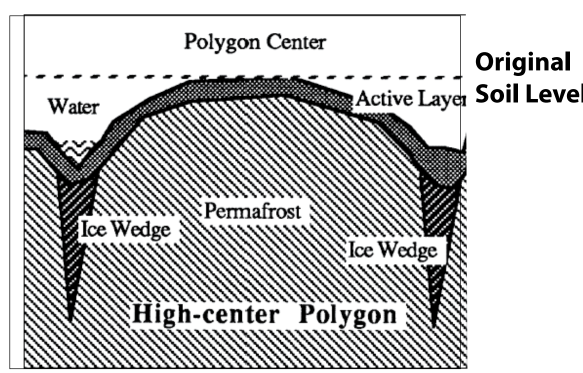
The pressure created by an ice wedge forces the soil around the crack upward to form two small ridges as much as 1 1/2 feet (0.5 meters) tall. This creates a polygonal shape of raised edges, or a low-center polygon.

In poorly drained sites, water fills the center of the polygon and the center of the ice-wedge troughs. Collected water efficiently conducts heat from sunlight so it melts underlying permafrost, which causes additional slumping.

As the water-filled troughs and centers enlarge and deepen, they eventually meet to form a small lake. When the lake is drained, or filled in with organic material, a new low-center polygon forms. Over a period of hundreds of years, poorly drained sites gradually cycle between flooded low-center polygons and small lakes.

In well-drained soil, the troughs around a low-center polygon enlarge and sink, while the center remains in place. It appears that the center of the polygon has raised, when actually, the troughs have sunk. The center may be 5 feet (1.5 meters) above the bottom of the troughs. As the thermokarst slumping caused by the growing troughs continues, the mound may eventually collapse, too.





Solifluction or Gelifluction

Little water can seep into permafrost soil. Thus, water from rain, melting snow, or melting ice in the surface soil is trapped in the active layer of soil.

On sloping land, the weight of the water-saturated soil causes the active layer to slide, or slump, downhill when thawed in summer. The rate of movement depends on the slope and amount of vegetative cover. Movement can vary from a fraction of an inch per year to an avalanche rush.

Sorted Rock Piles and Frost Boils

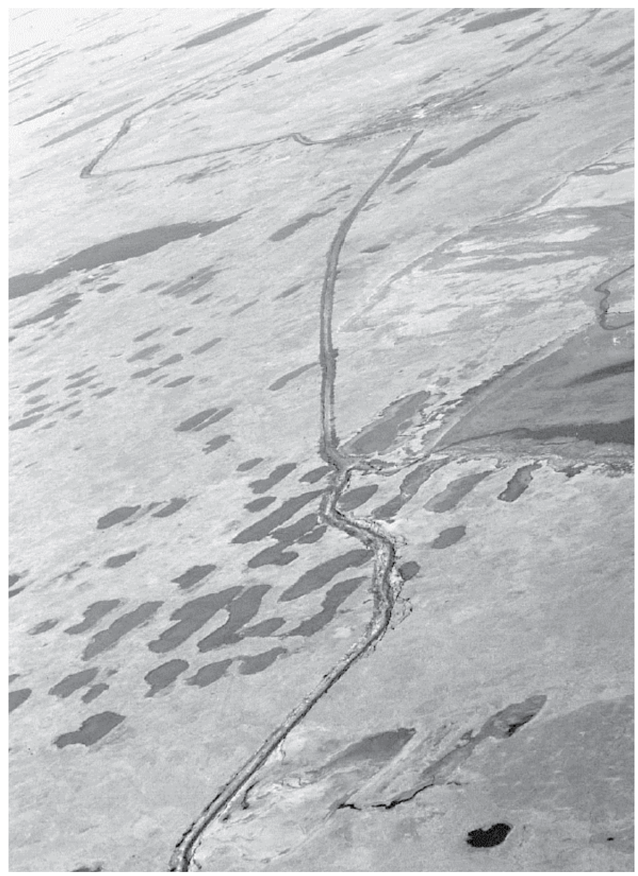
In soils containing rocks, the forces created by seasonal freezing and thawing move – and sometimes sort – soil particles. Although the exact processes that cause this are still debated, scientists agree that different rates of freezing and the forces of expansion, contraction, and gravity are involved.

Similarly to the creation of pingos, frost action first pushes noncompressible objects – large particles or stones – to the soil surface. When these formations occur in soil with water-filled, fine-grained soil, the expansion and contraction of this soil tends to move surface stones laterally across the ground. The movements create sorted nets, circles, and polygons rimmed by large- and medium-sized stones with centers of fine silt or clay material.

Thermokarst Slumping in Vehicle Tracks

A tracked vehicle left a swath of newly disturbed vegetation and compacted soil as it crossed the tundra (*photograph at left*) at Storkersen Point, northwest of Prudhoe Bay in 1971.

Five years later, this photograph was taken at the same location at Storkersen Point. The tundra disturbed by the tracked vehicle formed thermokarst depressions. Water from surrounding areas now accumulates in the ruts. Note that few plants have colonized the tracks after five years.



This 1971 aerial photograph shows a summer view of a winter road across the tundra near Oliktok Point. Thermokarst formation in the winter road has affected the surrounding tundra by causing drainage of large and small lakes.

The Ups and Downs of Life on Frozen Ground

ALASKA SCIENCE FORUM

June 2, 1999 (Article #1443)

by Ned Rozell

Creeping glaciers, ash-spouting volcanoes, and persistent earthquakes that rearrange the landscape make Alaska an exciting place to live. A less dramatic feature of Alaska's landscape, permafrost, is also changing Alaska as it slowly disappears.

Permafrost, ground that remains frozen all year, forms a foundation for about 85 percent of Alaska. From Barrow to Anchorage, most of the ground beneath our feet contains frozen soil and ice that sits in spaces between soil grains or takes the shape of wedges, lenses, and veins.

North of the Brooks Range, permafrost is generally found everywhere you might sink a drill. Farther south, permafrost is spotty but still plentiful. Alaskans have adapted to the challenge of building on permafrost with clever engineering tricks, but a warmer climate might soon make all our adaptations pointless.

Tom Osterkamp and Vladimir Romanovsky think permafrost might soon be on the minds of all Alaskans, and not just when they drive over waves of asphalt created by melting beneath. Osterkamp, a professor of physics at the Geophysical Institute, and Romanovsky, a research assistant professor here, just wrote a paper on the condition of Alaska's permafrost. The verdict: permafrost south of the Yukon River is quite near the thawing point, and, without a dramatic turn in climate, Alaskans are in for a messy transition.

For more than 20 years, Osterkamp has checked the temperature of permafrost using holes drilled in the ground on a transect paralleling the trans-Alaska pipeline. These "permafrost observatories" are also located in Anchorage, Utqiagvik (formerly Barow), Bethel, Bettles, Kaktovik, Nome, Kotzebue, Healy, and Eagle. The holes are from 100 feet to 200 feet deep, and with them Osterkamp and Romanovsky have been able to track the fate of permafrost for the last two decades.

Most permafrost south of the Yukon River is within two degrees Celsius of thawing. If a warming trend that began in the winter of 1976 – 1977 continues, the permafrost will melt. While getting the ice out of the soil may seem like a welcome relief to those who build roads, houses, bridges, and pipelines, it will be a bad thing for the thousands of people who now live on houses above permafrost and use roads, bridges, and pipelines built over permafrost.

Air temperatures in Fairbanks have increased 1.5 degrees Celsius in the last 20 years. During the same period, Bettles warmed by 1.4 degrees Celsius and Gulkana by 1.3 degrees Celsius. If the increase is consistent for the next 20 years, Alaskans are going to notice a dramatic difference in the world around us. Roads will slump, floors will slant, and huge sinkholes will appear in forests, swallowing trees and creating new lakes.

"The transition period will create whole new ecosystems," Romanovsky said. "It's a disaster for us, but not for nature."

And who's to blame for melting permafrost? Is it the species building the houses, roads, and pipelines? That's the big question—are humans causing global warming, or is the warming we've seen in Alaska since the 1970s a natural variation, one that could quickly reverse itself and preserve all this permafrost? Maybe the warming is a quirk of nature unaffected by man. Maybe not. All we know now is that one of Alaska's most visible signs of climate change is thawing right under our feet.

Science Forum articles are a public service of the Geophysical Institute, University of Alaska Fairbanks, in cooperation with the UAF research community. Ned Rozell is a science writer at the institute.
www.gi.alaska.edu/ScienceForum/

TUNDRA SOIL FORMATION

The presence of permafrost chills the soil and serves as a **limiting factor** to productivity in tundra ecosystems. Cold retards the rate of decomposition of organic materials and soil formation in the tundra, when compared with more temperate environments.

Cold and Decomposition

Successful decomposition depends on successful populations of **detritivores.** Often microscopic in size, detritivores eat wastes and the remains of living things that have died (see also INSIGHTS *Section 4)*.

Bacteria and fungi are the major detritivores in tundra ecosystems; very few insect detritivores are able to live in such harsh environments. Even bacteria and fungi slow down or become **dormant** in freezing temperatures *(*see also INSIGHTS *Section 3)*.

Cold Connections: The slow rate of decomposition profoundly influences the entire tundra environment and illustrates the web of connections.

(1) When decomposition is slow, **soil formation** is slow.
(2) When soil formation is slow, few plants have the nutrient base needed for growth.
(3) Fewer plants support fewer herbivores.
(4) Fewer herbivores means less food for carnivores and omnivores.
(5) The result is less organic matter (plant and animal) to be recycled into soil by decomposition.

And that cycles back to (1) where decomposition and soil formation limit productivity in tundra ecosystems.

One Advantage of Freezing: The tundra's climate does assist decomposition in one way: The process of freezing and thawing speeds access for bacteria and fungi to the insides of the cells of dead plants and animals. Water in cells expands when it freezes, breaking cell walls and opening the inner cells to invasion.

The overall effect of cold temperatures, however, is to slow the rate of decomposition.

Peat

Working under cold conditions and only during the summer months, tundra detritivores cannot even keep up with the available organic materials. Partially decomposed **detritus** collects, and the supply builds over time.

Accumulation Faster than Decomposition: These detritus repositories collect and hold water like a sponge and become **peat** (moist, partially decomposed organic materials). Few detritivores can function in those cold, water-saturated conditions. Accumulation occurs faster than decomposition.

One Meter in a 1000 Years: Peat grows at a rate of about 1 meter (39.37 inches) each 1000 years or about 1 millimeter (.04 inches) per year.

Alaska Leads Nation in Peat: Peat deposits cover about 4.4 percent of the earth's land surface, with the majority in Russia, Canada, and the United States. Alaska contains the largest U.S. peat deposits, about 125 million acres.

Peat becomes available for the action of detritivores and soil formation when exposed by erosion.

Lichen Soil Makers

With slow nutrient recycling and slow soil formation, the tundra would be much less productive if it were not for the abundance of lichens.

Lichen Colonize Bare Sites: The teamwork (**symbiotic relationship**) of algae and fungi working together enables lichens to grow best in environments where other plants cannot survive. Lichens often **colonize** barren areas. They are **pioneer plants** that can grow on rocks or surfaces without soil.

Because rocks provide neither water nor food sources, only the partnership of fungi (capable of storing atmospheric water) and algae (capable of producing food by photosynthesis) enables them to survive.

Lichens Break Down Rock: Lichens are critical in the formation of soil. They produce acids that dissolve the rocks, or other solid material on which they grow, to create new soil. Lichens also hold water that, as shown in the tundra topographic features, is a highly effective weathering agent.

In addition, lichens can trap windblown sand and plant debris to form a primitive soil layer that can later be inhabited by mosses, grasses, and higher plants.

Types of Lichens: Lichens come in many different forms. They have no leaves, roots, stems, or flowers. A close examination of rocks or ground will reveal a colony of delicate, hairlike filaments, some straight, some branched. **Foliose** lichens look like strange, large leaves. Some **fruticose** lichens are characterized by a crown of miniature "pixie cups." Some **crustose** lichens are vivid stains of green, orange, or black clinging to any surface.

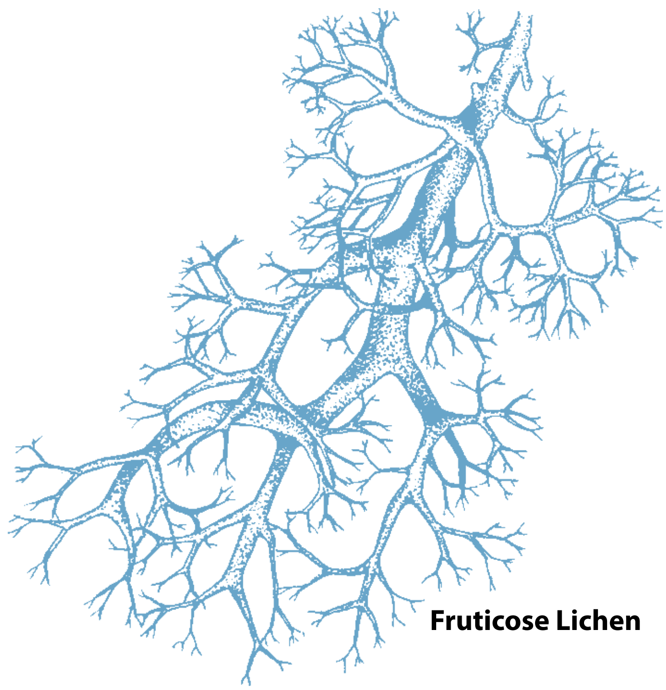
Approximately 2500 kinds of lichens live in the Arctic, almost 10 times the number of bird species found in all of Alaska.

Lichens are fragile and slow-growing. A lichen colony the size of a quarter may be 10 or more years old. They are sometimes called "time stains" because of their slow rate of growth.

Lichens are easily crushed, particularly when they are dry and brittle.

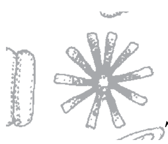
The Bottom Line for Soil

Because it takes a long time for soil to develop in cold climates, the bottom line is that any soil that does exist is of great value to the tundra ecosystem. Disturbance or damage to the soil impoverishes the food web and takes many years to heal.



Fruticose Lichen

Life Forms and their Tundra Adaptations



There are five life forms or kingdoms (highest biological classification) in the tundra as well as in the world. These range from the most familiar – plants and animals (including humans) – to the lesser known and seldom noticed fungi and microscopic monerans and protists.

The following pages introduce each of these five biological kingdoms and then highlight **adaptations** by some of their members to not only survive but also to thrive in the harsh tundra environment.

Tundra life forms have adapted to their harsh environments with physical, physiological, and behavioral traits not needed by others of their kind living elsewhere. Adaptations occur slowly over thousands of years. The traits that are kept are those of individuals that produce the most offspring. In *Alaska's Tundra and Wildlife*, the focus is on adaptations for cold environments.

1 AND 2 – MONERANS AND PROTISTS

Small but mighty

Although they are not as abundant in tundra as in milder environments, **monerans** and **protists** play a large role in creating soil. Until recently, these microscopic living things were considered to be small versions of plants and animals. But the more scientists learned about them, the less they seemed to fit in either category.

Some not only make their own food, as do plants, but also move around and catch and eat other living things. Additionally, the structure of the cells of many microscopic organisms is quite different from those of either plants or animals.

Today, most scientists agree that these microscopic organisms are not really plants, animals, or fungi. Scientists created two new kingdoms, based on the structure of their cells, for these microscopic living things.

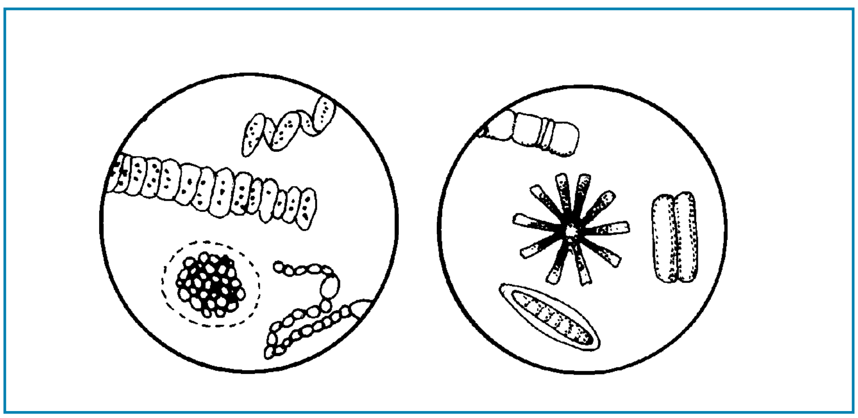
MONERANS: The smallest microscopic organisms, monerans, do not have nuclei in their cells. **Bacteria** and **cyanobacteria** (or **blue-green algae**) are examples of monerans. A million monerans would fit on the head of pin.

PROTISTS: Larger microscopic organisms that have cell nuclei are called protists. These include **algae**, **paramecia**, **amoebas**, and many others. Some protists live together in large groups that can be seen without a microscope, but the individual organisms are microscopic.

Some monerans and protists (including cyanobacteria and algae) are **producers**. Like plants, they are able to photosynthesize (to make food from air, water, and sunlight) and are food for very small animals.

Some of these microscopic creatures are **herbivores,** and others are **carnivores**.

Most, however, are **detritivores**, especially a majority of the monerans. Microscopic detritivores are primarily responsible for returning minerals in waste and dead things to the soil for reuse by plants and other producers.



Microscopic organisms are abundant and important in all ecosystems, including tundra. The majority are detritivores that replenish the soil with recycled nutrients.

3 – FUNGI

An out-of-body phenomenon

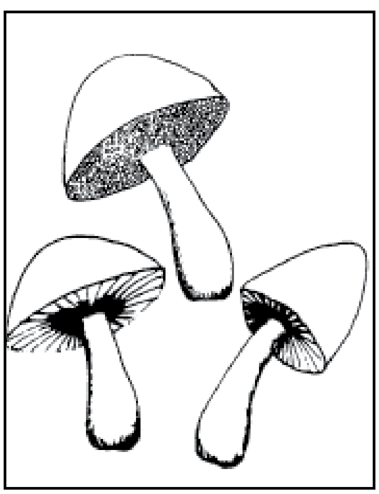
In tundra, fungi are more important and more prolific decomposers than bacteria. Fungi are well adapted to acidic soils. They are similar to plants in that they are immobile. In fact, scientists used to consider them to be plants. But fungi are very different from plants in cell structure and in the ways they live; scientists now place them in their own kingdom of living things.

Usually, we see only the fruiting, or reproductive, part of a fungi (*a mushroom, for example*). Its main body is hidden from view. The body of a fungus is made up of **hyphae**, microscopic hairlike structures that reach out through soil or into roots.

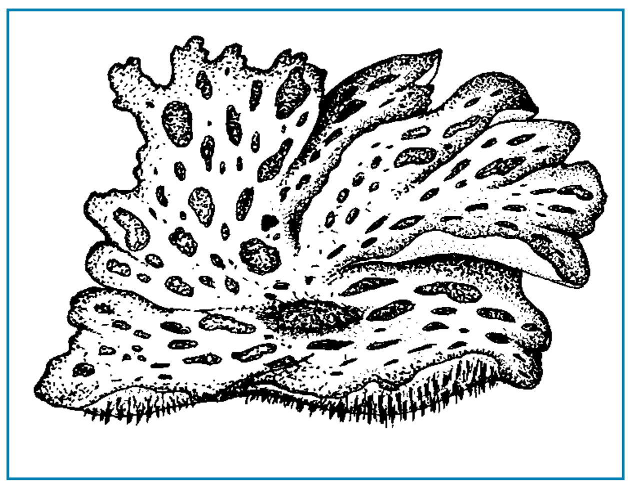
Fungi have an unusual way of eating: they use their hyphae and digest their food outside their bodies. The cells of fungal hyphae give off digestive enzymes like those found in our own stomachs. These enzymes break down wood, leaves, and other material. Then the fungal hyphae absorb the scattered sugars and minerals and use them to grow.

Many kinds of fungi – including molds, lichens, mushrooms, and microscopic forms – are present in tundra ecosystems. Some fungi form symbiotic associations with plants and help them obtain needed minerals from the soil in exchange for the sugars the plant produces.

A lichen, the most visible of the fungi in tundra, is actually a partnership between a fungus and an alga. Lichens are most abundant on dry sites such as alpine tundra ridges, on frost boils, or on the tops of high-center polygons in lowland tundra. Specially adapted varieties of aquatic fungi dwell in wet lowland tundra.



Mushrooms are the fruiting, or reproductive parts of certain fungi. Tiny hairlike structures, called hyphae, are the main body of most fungi.



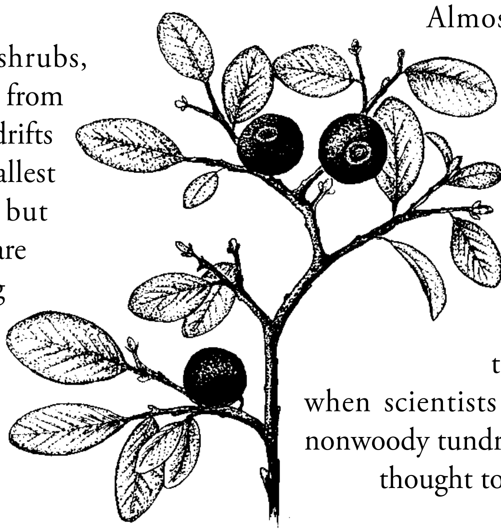
Lichens are the most visible fungi in tundra ecosystems.

4 – PLANTS

Measured in inches

Trees are conspicuously absent from tundra ecosystems. Nevertheless, the texture of the tundra is rich with many other species of plants.

Woody plants are limited to shrubs, mostly along waterways sheltered from wind and covered by deep snowdrifts in winter. Some willows (the tallest shrubs) grow several feet tall, but more commonly willow shrubs are prostrate or creeping, spreading *outward along the ground* instead of growing skyward. They, like the majority of other tundra plants, grow only a few inches high.

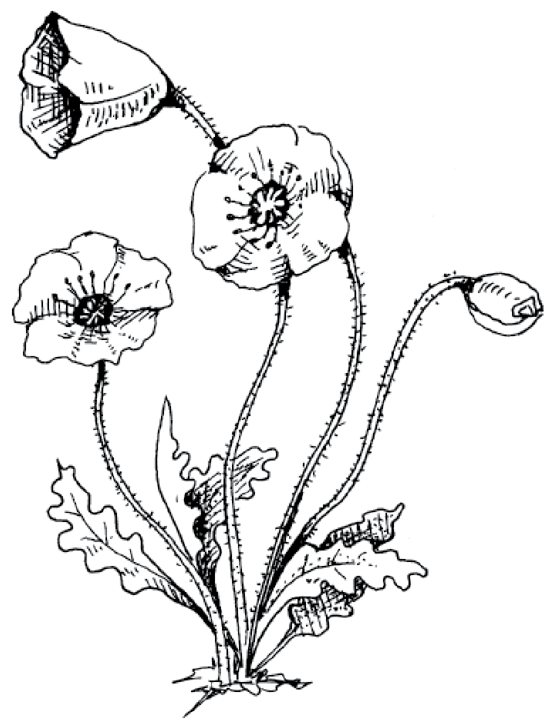


Mosses and lichens are abundant in tundra ecosystems. Grasses and sedges are the most important vascular plants in wet tundra, while small woody shrubs in the heath family dominate dry sites on both alpine and lowland tundra.

A meager three months each year are suitable for plant growth in most tundra areas. Consequently, plants are primarily perennials, adapted to a multiyear growth cycle to store enough energy and minerals to reproduce.

Almost all tundra plants are able to reproduce by root sprouts or runners to avoid the energy drain of setting seeds in the short, cool summers.

Most tundra plants live for a remarkably long time. One rhododendron, a small, woody tundra plant, had lived 300 years when scientists counted its annual rings. Even nonwoody tundra plants are thought to live for decades.



5A – ANIMALS (Invertebrates)

Summer hordes

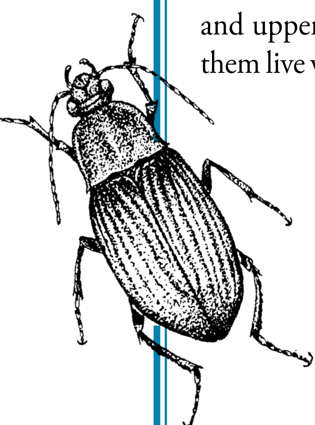
Tundra **invertebrates** are only active and visible during the summer. In the brief warm months, flying insects such as bumblebees, ichneumonid wasps, moths, butterflies, crane flies, and midges are conspicuous. Mosquitoes and various biting flies occur in great abundance!

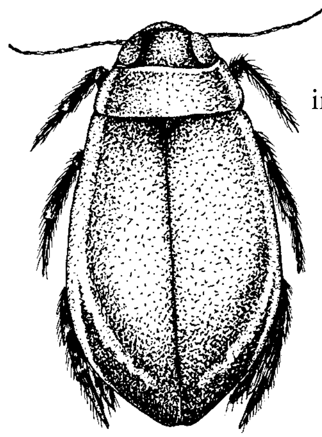
Other kinds of invertebrates are present, but more careful searching is required to see them. Sawflies, aphids, rove beetles, carrion beetles, and ground beetles are among the insects that live on plants or in moss. Spiders and centipedes are also present.

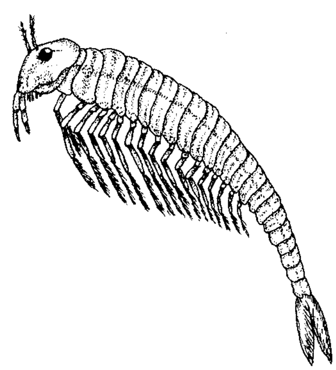
The greatest number and variety of invertebrates in tundra occur in the moss and upper few inches of soil. Nearly all of them live within 2 inches (5 centimeters) of the soil surface because they need external warmth to function. These soil-dwelling invertebrates feed on dead organic material, bacteria, protozoans, and each other.

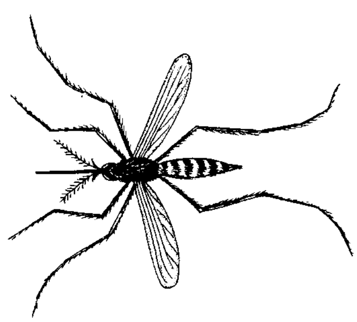
Earthworms, mites, springtails, and flies (including mosquitoes) are the most common invertebrates in the tundra. Of these, the insects, springtails, and flies are the most notable.

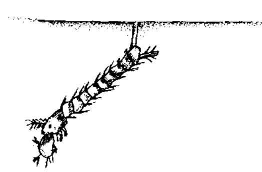
Invertebrates that feed on plants (**herbivores**) are scarce in tundra environments. The majority of tundra invertebrates eat dead plants and animals. These invertebrate **detritivores** include worms, mites, and fly larvae.







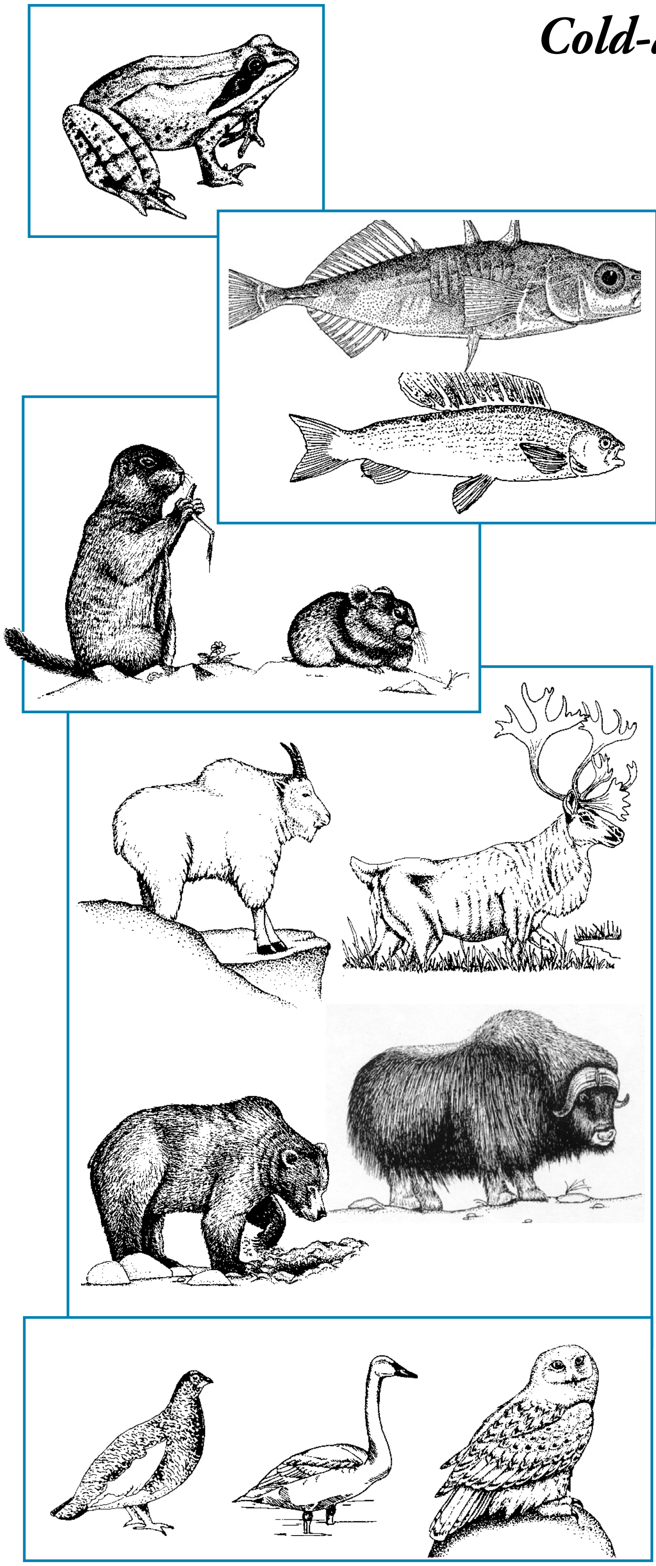




FIVE KINGDOMS OF TUNDRA LIFE

5B – ANIMALS (Vertebrates)

Cold-adapted



Reptiles are the only major group of **vertebrate** animals absent from tundra ecosystems. A single species of amphibian, the wood frog, occurs in tundra areas throughout much of Alaska, but has not been found in far northern tundra.

Most tundra lakes, ponds, and even rivers freeze completely during winter. Several kinds of fish survive in tundra by migrating to the deepest holes in rivers or lakes not solidly frozen. Arctic char, grayling, whitefish, ciscos, lake trout, blackfish, three-spine and nine-spine sticklebacks, burbot, and slimy sculpins are among the most common fish in tundra waters.

A variety of mammals live in *both* alpine and lowland tundra; these include shrews, lemmings, voles, arctic ground squirrels, mink, weasels, wolverines, red foxes, wolves, brown bears, and caribou. Pikas, marmots, Dall sheep, and mountain goats live mainly in alpine tundra. Muskox, tundra hares, and arctic foxes inhabit lowland tundra.

Several tundra species are restricted to particular regions of Alaska. Mountain goats, for example, occur in alpine tundra only in southeast and southcentral Alaska. River otters, muskrats, and beavers are abundant in lowland tundra of western Alaska, but are absent from tundra on the North Slope.

The only birds remaining in tundra environments year-round are ravens, snowy owls, gyrfalcons, three species of ptarmigan, and snow buntings. Even these species move out of those tundra areas where winter conditions are most harsh.

Migration

Migration is an adaptation for avoiding the worst and enjoying the best of tundra environments.

Many birds, mammals, and fish enjoy the summer riches of the tundra and then avoid the winter by migrating to milder locations. The seasonal movements of large numbers of animals into and out of tundra environments are among the most spectacular natural events in the world.

Each spring, huge flocks of shorebirds and waterfowl rush toward the tundra. Areas with no visible life suddenly come alive with the movements and calls of arriving migrants. As soon as enough snow melts, these birds spread over the tundra in low densities to nest. When they and their young gather before hurrying south, the surprising productivity of the tundra is once again revealed.

The gathering places of migrants, called *staging areas*, are fixed locations where food is abundant so the migrants can fuel up for their long travels. Some migrant birds nearly double their weight with layers of fat before leaving.

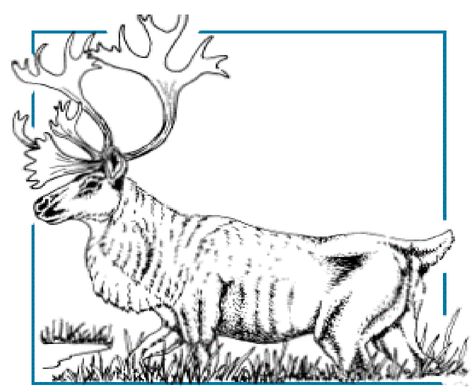
Many birds travel thousands of miles to wintering areas in Central and South America or Polynesia. Some birds such as ptarmigan migrate relatively short distances. They move south out of arctic tundra areas and down slope from high alpine areas to low alpine or forested areas in the interior of Alaska.

The migration of caribou between tundra areas and **taiga** or forest environments is one of the best known examples of migration by mammals. Caribou come to the tundra to give birth to their calves just as the tundra plants become most nutritious.

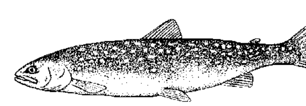
Many tundra fish also migrate. In fall, they move into places where the water will not freeze solidly. Deep lakes, deep channels in large rivers, and spring-fed streams are important winter habitats for tundra fish.

Whimbrels nest in tundra but migrate to spend the winter on the Pacific coast from California to Chile. Most shorebirds migrate thousands of miles to return to the tundra from southern wintering areas.

Ptarmigan migrate out of the northernmost tundra regions to winter in the low alpine tundra and forests of central Alaska.



Caribou migrate out of tundra areas to winter in taiga and forests.



Tundra fish, such as arctic char, migrate to places where some water remains liquid throughout winter.

TUNDRA ADAPTATIONS

Shelter

Because they find shelter from the severe winds and cold, many living things remain on the tundra year-round.

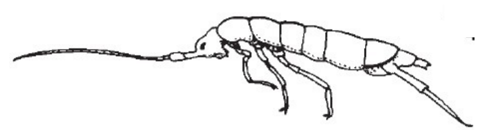
The small mammals, insects, and plants living in the tundra cannot migrate to distance places to avoid the severe winter conditions. Their adaptive strategy is to remain beneath the snow, near the ground. Lemmings, for example, tend to live together in areas where the snowpack is deepest and least dense. This type snow shelters them from the wind and offers some protection from the cold of winter. In contrast, dense, wind-packed snow is a poor insulator and provides only limited protection from the cold.

Some animals, such as the arctic ground squirrel, move underground for winter. Soil, like snow, provides insulation against the cold and wind. Many plants have a similar adaptation: their above-ground parts die back each winter, while their main growth and energy storage is in their underground roots, sheltered by soil and snow.

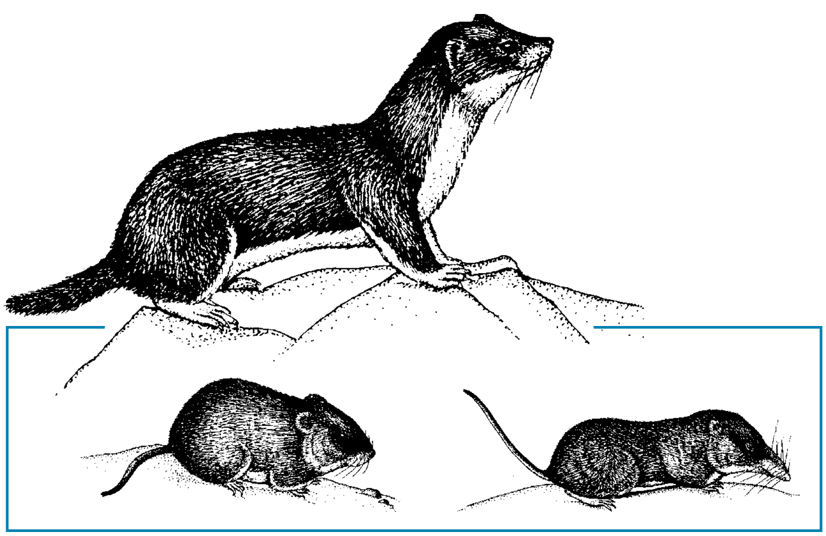
The cool temperatures and strong winds of tundra summers also call for special adaptations. The answer for many is to live close to the ground. Just place your hand on the ground to feel the advantage – it's WARM! Due to friction, the wind speed within 2 inches (5 centimeter) above the ground is slower. The air is also warmer near the ground than higher above it because soil absorbs and radiates heat from the sun into the air.

Tundra plants typically are small and grow in flattened, cushionlike forms. Many tundra insects live their entire lives in the shelter of ground plants, thus avoiding the most severe cold and wind. Wingless forms of many insect groups are the most common in tundra environments. Arctic ground squirrels and brown bears dig their underground dens on south-facing slopes that will be the first to warm in spring.

Air temperatures are warmer and winds are slower near the ground's surface. Many tundra plants, such as moss campion, grow in low, flat mats or cushions to take advantage of these milder conditions.



Wingless insects are common in tundra environments. They spend their entire lives in the shelter of soil, mosses, or other plants.



Lemmings, voles, shrews, weasels, arctic ground squirrels, insects, and most plants survive the winter winds and cold by living beneath the snow. Temperatures under a blanket of deep, soft snow are usually 20°F (7°C) warmer than the air temperature above the snow.

TUNDRA ADAPTATIONS

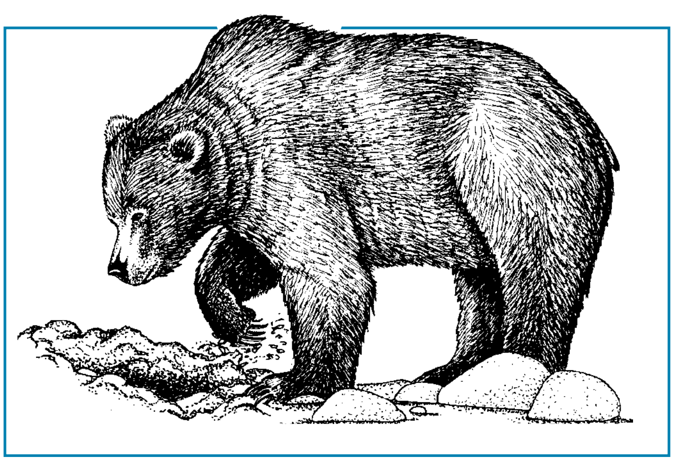
Food

Scarcity of food in winter prompts a range of adaptations from dormancy and hibernation to stocking up.

Sheltering near or under the ground is only half the survival mechanism for some tundra life that stays year-round. Plants, insects, and microscopic organisms simply cease functioning during the tundra winter. They stop moving, growing, and breathing during the winter, so they have no need for food. Birds, mammals, and fish, however, cannot survive unless they continue to breathe, thus they cannot become **dormant**.

Some animals survive by reducing their functions to the minimum needed for survival. Arctic ground squirrels and marmots **hibernate**. During winter, an arctic ground squirrel's heart beat slows from 200-400 beats per minute to 7-10 beats per minute; its body temperature lowers from 97º to 62°F (36º to 17°C); and it breathes only three times each minute instead of 60 times. While hibernating, a ground squirrel uses 98 percent less energy than while awake.

Brown bears survive winter in a modified hibernation. Their heart rate is slows from 50 or 60 beats per minute to 20 beats, but their body temperature is not reduced.

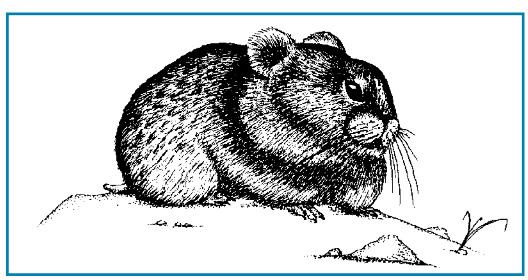


Brown bears eat only during four to five months of the year. Some lose up to 60 percent of their body weight during winter when they must live off the energy stored in their fat.

Arctic ground squirrels, marmots, and brown bears must eat enough food in four months of summer to maintain their body functions during eight months of sleep. They store this needed energy as layers of fat. In tundra habitat, a brown bear weighing 300 pounds (136 kilograms) in fall emerges from its den in spring weighing less than 200 pounds (91 kilograms) because it used its fat – energy reserves – while in its den.

Other tundra animals, lemmings for example, remain active and even raise young during winter. They survive by feeding on the energy-rich buds, stem bases, and **rhizomes** of dormant plants. Pikas and singing voles remain active during winter and survive by eating food they cached for winter use. During summer, pikas busily gather and dry grasses in the sun, then store the hay near their nests. Singing voles build large piles of grasses and other plants for winter food.

Humans may die if their body temperature drops below 90°F (32°C) for even a short time; arctic ground squirrels, however, lower their normal 97°F (36°C) body temperature to only 62°F (17°C) during hibernation. This greatly reduces their need for energy.



Pikas cut grasses and other plants, dry them in the sun during summer, and store the dried hay underground as a winter food supply.

TUNDRA ADAPTATIONS

Size and Shape

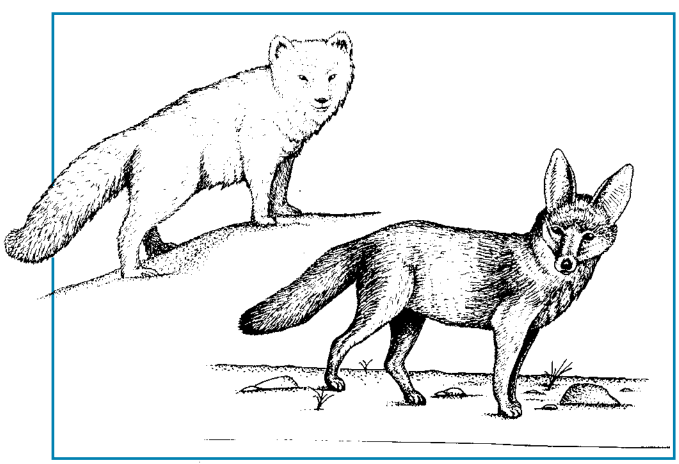
Large size and short appendages are adaptations that help tundra animals keep warm. "Small" works best for plants.

Many tundra birds and mammals are larger and have smaller appendages than do similar species living in warmer environments. Tundra hares, for example, are among the largest hares and have shorter ears and legs than do desert hares (called jackrabbits).

Similarly, arctic foxes have shorter ears than do desert kit foxes. Even lemmings are larger and have smaller ears and tails than do most other mouselike animals. Large body size and short appendages are adaptations that reduce heat loss and resist the cold.

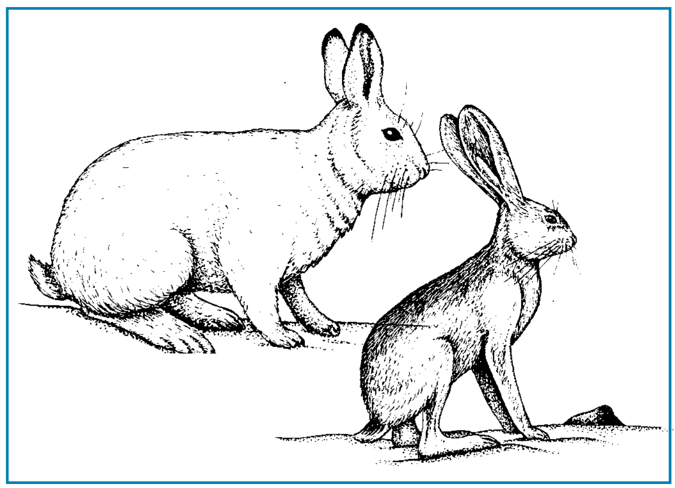
The amount of heat loss increases as the ratio of exposed surface area to body weight increases. Because small animals have more surface relative to their weight than do large animals, they lose heat more quickly. An animal with long legs, ears, or a tail has more surface area than does an animal of the same size that has shorter appendages.

Small size, however, can also be an adaptation for survival on the tundra. Why? A small organism can survive on less food than can a large organism of the same species. Very small organisms can live under the snow and avoid the most severe conditions of winter. Shrews, the smallest of all mammals, thrive in the tundra.

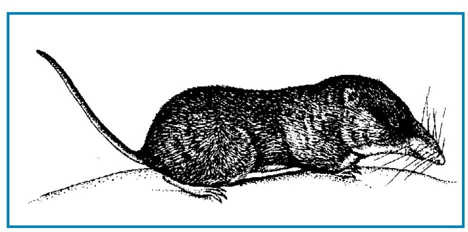


Arctic foxes have shorter ears than desert kit foxes.

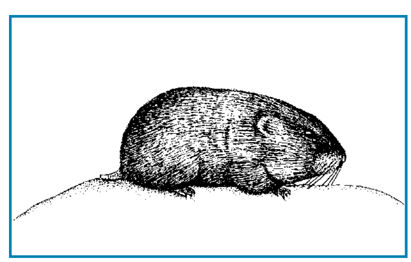
Tundra plants are often dwarf relatives of similar plants from milder climates. Short plants can better avoid drying and abrasive winds and stay warmer in the near-ground microclimate. Their small flowers save energy.



Tundra hares are larger and have shorter ears than hares that live in hot environments.



Small animals such as shrews are able to keep warm on the tundra despite their small size, in part because they can live under the snow.



Lemmings are large and have smaller ears and tails than most other mouselike animals.

TUNDRA ADAPTATIONS

Fur, Feathers, and Movement

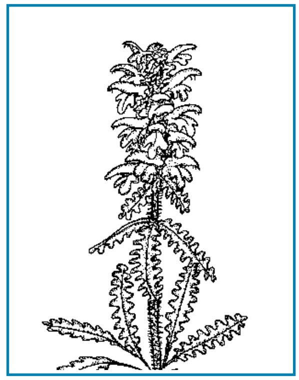
Most tundra organisms have insulation to help them stay warm.

Feathers and fur are the most obvious adaptations for life in a cold environment. Most tundra birds and mammals actually wear two coats. Their outer coats are made of tough, coarse, water-repellent feathers or guard hairs. Their inner coats are soft, fluffy feathers or hairs that trap air. Even at temperatures of –29°F (–34°C), ptarmigan can keep their body temperatures at 104°F (40°C) without increasing their respiration rate. Caribou and muskoxen have hollow hairs that are fatter at the tip than at the base. This shape helps trap a layer of air next to the body. Trapped air provides excellent insulation.

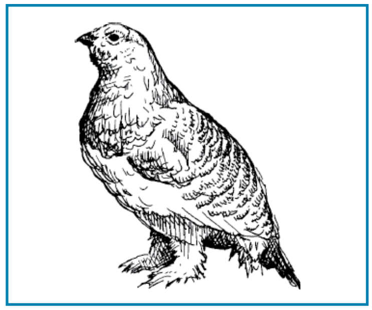
Even tundra bumblebees wear an insulating coat of dense body hairs that slows heat loss. They "shiver" their flight muscles to generate heat, which is temporarily trapped within their velvet coats. They can keep their body temperatures 68 - 86ºF (37 - 47ºC) above air temperatures, allowing them to be active at colder temperatures when the other cold-blooded insects are grounded. The chemical reactions necessary for movement need heat.

Many tundra plants also wear adaptive coats – furry and waxy coatings on their leaves and stems. Fine hair or fuzz slows the wind, thus reducing drying and preserving heat. Dense hairs around the flowers of the woolly lousewort also act like the glass of a greenhouse – trapping solar energy. This surrounds the flowers with relatively warm air, sometimes 34ºF (18ºC) warmer than the environment. This is important because cell division, necessary for seeds to form, cannot occur at cold temperatures.

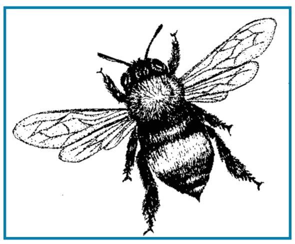
The waxy coating of many plants also reduces water loss and evaporative cooling by the wind. Many tundra plants retain, rather than shed, their dead leaves each year. The dead leaves insulate fragile new buds from the wind and cold. Grass tussocks provide a good example of this.



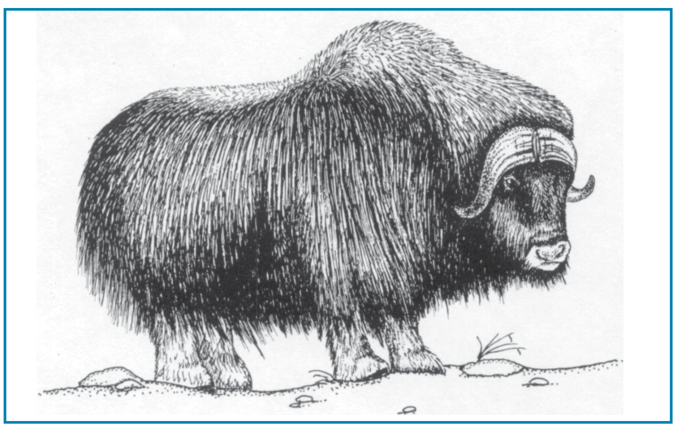
Woolly lousewort, a tundra plant, is covered with hairs that help block the wind and trap warm air around its leaves and flowers.



Ptarmigan, whose feathery coats cover even their feet, have the best insulation of any tundra bird.



Tundra bumblebees have dense, velvet-like hair that helps them keep the heat they generate when they move their wing muscles.



A double coat of dense hair helps muskoxen stay warm even when the air temperature is -40°F (-40°C).

TUNDRA ADAPTATIONS

Color

Tundra organisms use color to increase heat absorption or to hide from predators.

Dark colors absorb solar energy, and light colors reflect it. One would expect that, to take advantage of summer sunlight, organisms living in cold tundra environments would be darker than organisms living in warmer environments. However, dark objects also radiate and lose heat more rapidly than do light objects, therefore during winter, some organisms reduce heat loss with white coloration.

Many of the tundra's summer flowers are purple or blue because these colors absorb more heat than do white or light yellow. Indeed, the percentage of dark-colored flowers is greater in the tundra than in warmer environments. Certain tundra insects, active in the summer, are darker than related species occurring in warmer habitats.

The value of a dark color can be increased by an organism's behavior. For example, many butterflies bask in the sun with their dark wings spread wide to absorb heat.

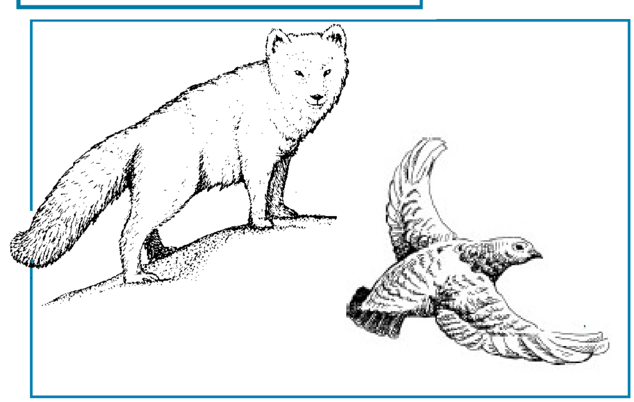
Surprisingly, the light coloration of yellow arctic poppies and other flowers is also an adaptation to the cold environment. The flowers of these plants are **heliotropic**; they turn to face the sun. The shapes of the light-colored petals reflect sunlight toward the flower center where the seeds are produced. Several kinds of insects bask in the centers of these heliotrophic flowers and benefit from the focused solar heat.

For survival, sometime protection or hunting success is more important than heat absorption. Many arctic animals change colors seasonally to use the advantage of camouflage throughout the year. White fur and feathers hide animals in the snow. White coloration helps collared lemmings, ptarmigan, and snow buntings escape their predators.

Some predators also use color to their advantage. Weasels and arctic foxes change color seasonally, and that helps them sneak up on their prey. Polar bears that den in winter in the coastal areas of the arctic tundra are white year-round because they rely on camouflage for surprise as they hunt on the sea ice.

More tundra plants have blue or purple flowers than do plants in warmer environments because these colors absorb more solar energy.

Most tundra insects are darker than related insects in warmer environments.



Many warm-blooded animals that live in tundra have white fur or feathers during winter for camouflage and to reduce heat loss.

TUNDRA ADAPTATIONS

Antifreeze

Some tundra organisms make antifreeze.

Humans add antifreeze to water in vehicles to prevent the water from freezing in winter. This antifreeze is ethylene glycol, a fluid that freezes at a temperature lower than the freezing point of water.

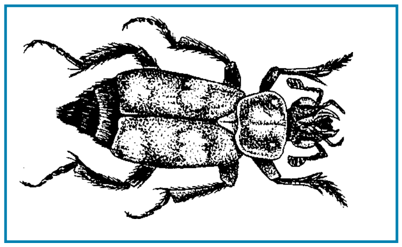
Most living things are 70 percent water. When water freezes, it expands as it forms ice crystals. If this occurs in a living organism, cells burst or are damaged. Repeated freezing and thawing are particularly hazardous for living tissue, yet these fluctuations are characteristic of summer temperatures in tundra environments. How do living things survive these conditions?

Some organisms overcome this problem by producing chemicals that lower the freezing temperature of cell fluids. These antifreezes prevent the formation of large ice crystals within the cells, even at very low temperatures.

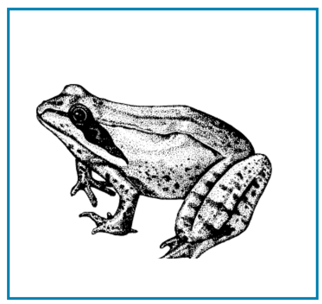
Because of the antifreeze in their blood, wood frogs can survive temperatures of 21°F (–6°C). Most arctic insects produce glycerol, which is an effective antifreeze. If cooled slowly, certain arctic insects can withstand temperatures of –76°F (–60°C). Mosquitoes can survive temperatures down to about –25°F.

Some tundra fishes also have antifreeze. The Alaska blackfish is able to breathe air through its esophagus in addition to getting oxygen from water through its gills. It can survive temperatures as low as 4°F (–16°C), and some have survived being partially frozen for 45 minutes. Some parts of the fish must remain unfrozen, however, for it to survive.

Plants need antifreeze not only to prevent freezing, but also so that they can make enough food to survive. Because the process of photosynthesis requires water, many plants cannot function if the temperature is less than 32°F (0°C), the freezing point of water. But air temperatures in tundra environments frequently drop below freezing in spring, fall, and even summer. Many tundra plants, such as the tundra grass, are able to photosynthesize at temperatures of 25°F (–4°C) because they produce antifreeze that keeps their cell fluids liquid even at this low temperature.



Some tundra insects can withstand temperatures of –76°F (–60°C).



Wood frogs can withstand temperatures of 21°F (–6°C).

Many tundra plants, such as the tundra grass, can photosynthesize sugars at temperatures below the freezing point of water because they produce antifreeze.

Growth and Reproduction

Most tundra animals grow slowly and raise young only when conditions are favorable.

Growth and reproduction require food – energy and minerals. Any organism growing faster than it is able to obtain food starves to death. Similarly, an animal that produces young when food or other conditions are unfavorable reduces its own chances for survival as well as the chances for survival of its offspring.

Food availability and weather are variable in tundra environments. Thus, opportunism, or the ability to adjust growth and reproduction according to environmental conditions, is a survival adaptation in tundra environments.

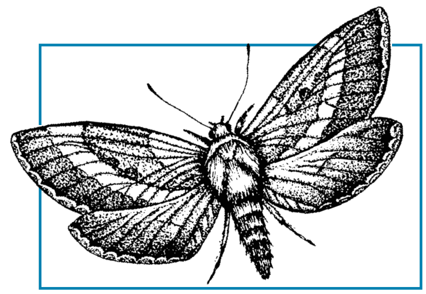
Most cold-blooded tundra organisms grow slowly or not at all when temperatures are too cold. They do not reproduce until they reach a certain size and conditions are favorable. For example, certain arctic moths may require up to 10 years to develop into adults. In milder environments, the same species can reach adult size within two years. Similarly, lake trout in the tundra need 10 years to grow to adulthood, compared with five or six years needed by a lake trout living in nontundra lakes.

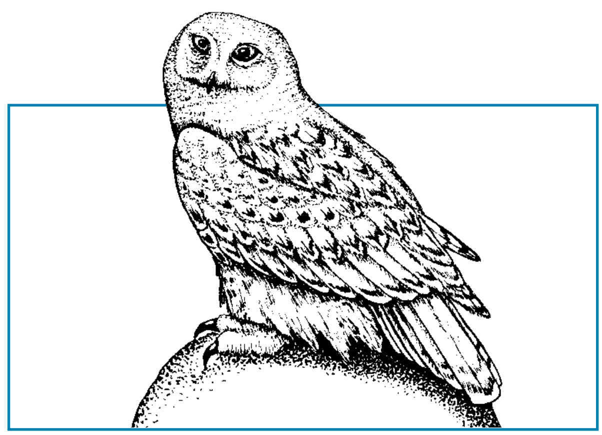
Brown bears living in northern tundra of Alaska do not begin breeding until they are eight years old; they give birth to only two young every four years. Compare this to brown bears of southeast and southcentral Alaska – they begin breeding when three or four years old, and give birth to two or three young every three years.

Some migratory birds, including geese, swans, and shorebirds, lay fewer eggs or none at all when winter snows melt late. They save their energy for another year when food will be more plentiful.

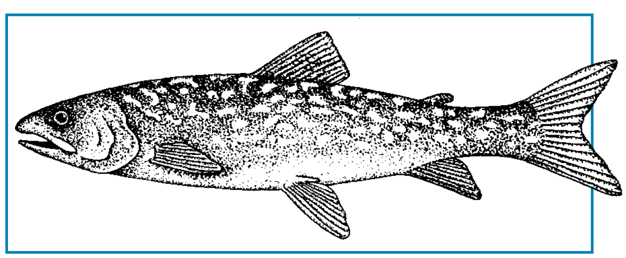
Predatory animals such as jaegers, snowy and short-eared owls, rough-legged hawks, arctic foxes, and weasels produce more young in years when lemmings (their main prey) are abundant. When lemmings are scarce, some of their avian predators do not nest.

Most tundra insects grow very slowly. Certain moths live 5 to 10 years before becoming adults.





Predatory birds such as snowy owls do not nest when lemmings (their main prey) are scarce.



Lake trout living in tundra lakes do not reach adult size for about 10 years because of short growing seasons, low temperatures, and scarcity of food.

Plant Growth

Tundra producers beat the short growing season with long life cycles.

As with an iceberg, there is more to tundra plants than what you see on the surface. Aerial parts are reduced in favor of root mass in the protective soil. This is also an adaptation used by many desert plants. Tundra plants tend to form clumps or cushions, which create milder microclimates (as much as 20 degrees warmer) to insulate growing tissues and preserve moisture. Keeping their dead leaves is such an adaptation.

Arctic tundra plants can grow at lower temperatures than can similar plants in milder environments. The energy and minerals stored in their large roots allow the plants to start to grow instantly in the spring – even under the snow.

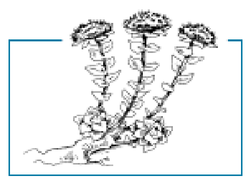
Tundra plants further make up for the short growing season by adopting long life cycles to accomplish reproduction. Many tundra plants grow for 10 years or more before saving enough energy to form flower buds. Even then a plant might form flower buds one year, bloom the next, and make seed a year later.

The fragile flower buds develop underground or encased by dead leaves so they are well insulated. When spring comes, the tundra can literally burst into bloom because the flower buds were formed in previous years.

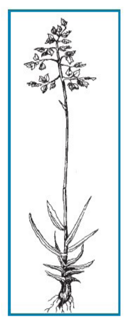
Many plants reproduce by rootstocks or runners instead of, or in addition to, seeds. The tiny plants that sprout from rootstocks are identical to their parent plant. The parent plant nourishes the clone plants until the clones have many leaves of their own.

Some plants, such as the alpine poa, produce seeds that germinate and begin to develop while still attached to the parent. This is an advantage, because when the young plants drop from the parent, they already have tiny leaves and can begin photosynthesis immediately.

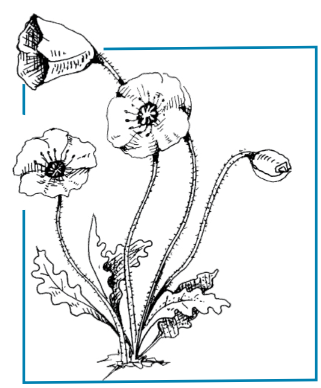
Alpine tundra plants can photosynthesize under widely fluctuating temperatures, in brilliant light, and in short periods of daylight. Arctic tundra plants can photosynthesize at low temperatures, at low light intensities, and for long periods of daylight.



Many tundra plants reproduce by rootstocks or runners.



The seeds of alpine poa germinate and grow while still nourished by the parent plant.



Tundra flowers bloom from buds that are one to two years old.

Most tundra plants are several years or decades old. The age of some woody tundra plants has been estimated at 200 to 300 years, based on counts of their annual rings.

Insect Insider Tips

“Cold-blooded” organisms find ways to keep warm, use less energy, and ensure reproductive success.

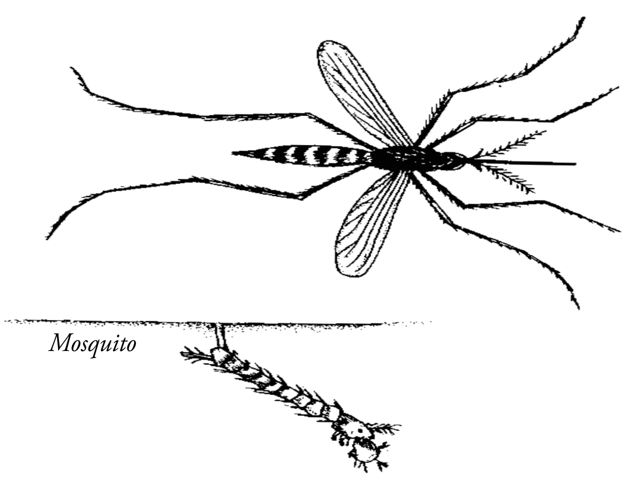
Cold, short growing seasons, relatively little plant life, and variable day lengths have led to extraordinary adaptations in life span, reproduction, and behavior for tundra invertebrates (earthworms, mites, **springtails,** and flies are the most common).

Unlike invertebrate animals in warmer climates, tundra invertebrates live much longer (except for many mosquito species). Tundra invertebrate species tend to have long **larval stages** (sometimes years) and very short adult stages. This life-cycle adaptation is a means of taking advantage of the stage in which the animals live and grow in the protection of the warmer soil layer.

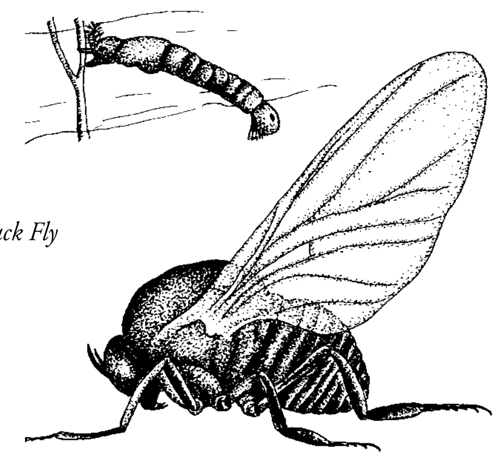
For example, woolly bear caterpillars spend much of their long lives in the larval caterpillar stage before their brief lives as moths. This reduces their energy consumption and their exposure to risks. These big, active caterpillars are clothed in long, rusty orange “hairs” for added warmth. The caterpillars can live as long as five years. Like most invertebrates, they are **dormant** in winter and develop only during the short summer.

Many tundra invertebrates have flexible life cycles. Some arctic blackflies develop eggs while they are still **pupae**. When they finally emerge from a stream as flies, their eggs are mature and they need only to mate and lay eggs during the few days of their adult life.

Tundra insects also have behavioral adaptations for surviving on the tundra where just keeping warm requires the majority of their energy. Instead of flying, many tundra insects crawl because the energy cost of flying is so great.



Mosquito



Black Fly

Tundra Ecosystems – Community Connections

Section 4
TUNDRA INSIGHTS

Energy Transfer – the basics of all life

Where the next meal comes from is a constant priority in any organism's life. In the tundra, this priority is especially critical because food sources (energy) are not abundant, and the slow organism may lose not only a meal but also its life. The following pages describe how energy is transferred and recycled in the tundra environment. Recycling here is not just an option, but is critical to continued survival of the ecosystem.

FOOD WEBS – who eats whom?

[See *Alaska Ecology Cards* for species illustrations and *INSIGHTS 3* for the "Five Kingdoms of Tundra Life".]

A plant is exquisitely equipped to convert the nonliving – air, water, minerals, and sunlight – into food for itself and others. Plants and algae that make food from nonliving materials are called **producers**.

The other living things in the tundra that depend on food manufactured by producers are called **consumers**. Consumers divide into four groups: **herbivores** (animals that eat plants), **carnivores** (animals that eat other animals), **omnivores** (animals that eat both other animals and plants), and **detritivores** (animals and other organisms that eat dead or decaying material).

The pathway of **energy** and **minerals** from the nonliving environment, through producers, to consumers, and back again through detritivores creates a **food chain**. All the food chains of a tundra are connected into a **food web – the energy circulatory system of an ecosystem**.

Energy Lost and Found: At each intersection in the web, some energy is returned to the nonliving environment as heat. That energy is not passed on and cannot be reused by living things. The lost energy is replaced during photosynthesis by the capture of energy from the sun.

Mineral Recycling: Minerals are always passed along at each web intersection until the detritivores return them to the environment in their original form, where producers can use them to make new food.

Producers Convert Raw Materials

Using the process of **photosynthesis**, producers combine energy from sunlight with carbon dioxide from the air and minerals from water, soil, and rocks to produce the

sugars and oxygen that help all other living things survive. Plants, algae, and lichens are important producers in tundra ecosystems and are the first life forms in food chains.

Unique in the World: Tundra producers are unique among producers in the world. Because lack of light (from darkness or snow cover), cold temperatures, and lack of moisture, they can only function for a few months each year. Ironically, this means that tundra producers are also tundra inhibitors – slowing and limiting the flow of energy and minerals through the ecosystem. [*Detritivores are another* **limiting factor***; see below.*]

Scientists measure this flow of energy and minerals by determining the weight of carbon that is "fixed" or changed into living material by producers each year. Basically, the measurement is the dry weight of all new growth – leaves, roots, flowers, seeds – produced each year.

Low Productivity in Tundra: On average, all tundra producers together make only one-tenth to one-third as much food each year as producers in forest ecosystems. As a result, tundra consumers are limited by a shortage of food unless they migrate elsewhere for part of the year (see *"Migration"* in *INSIGHTS Section 3*).

Herbivores Eat Producers

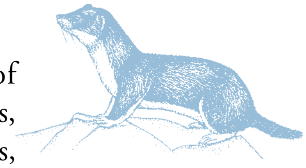
Some of the largest and smallest tundra wildlife are herbivores. Caribou and lemmings receive all their nutrition from plants. A caribou, however, must roam great areas of lowland tundra and migrate to obtain enough food to sustain its body mass.

Geese, also migrants, are tundra herbivores in the summer when plants are at their peak production.

Compared with forest ecosystems, relatively few plant-eating invertebrates occur in either alpine or lowland tundra environments. The tundra has herbivorous bumblebees, moths, butterflies, and a few sawflies, but these consume much less green vegetation than do vertebrate herbivores.

In alpine tundra, voles, pikas, marmots, Dall sheep, and mountain goats are the main plant consumers.

Carnivores Eat Herbivores – and Each Other



Tundra herbivores are prey of tundra carnivores such as wolves, wolverines, arctic foxes, weasels, jaegers, snowy and short-eared owls, gyrfalcons, and golden eagles. All will eat each other if the opportunity arises.

Birds Seek Insects: Flocks of small, insect-eating shorebirds that migrate to the tundra to nest are major carnivores in the ecosystem despite the relative scarcity of insect herbivores. Goslings and ducklings also rely on insects for a protein boost during their first few weeks of life while the parent geese and ducks eat plants and algae.

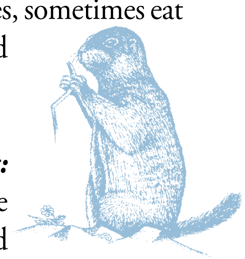
The insect-eating invertebrates in tundra ecosystems include some predatory crane flies, spiders, and ground and rove beetles.

Predator – Prey Dependency: Carnivores cannot survive without adequate populations of prey. Thus, the numbers and kinds of herbivores on the tundra determine, in part, the presence and abundance of carnivores.

Carnivores also influence the numbers and kinds of herbivores on the tundra. If a population of herbivores grows too large, the animals may eat all their food supply and starve. Maintaining healthy populations of carnivores reduce the chance of such herbivore population explosions and crashes. When a population explosion does occur, carnivores lessen the impact on plants.

Opportunistic Omnivores

Food on the tundra is often scarce; therefore, consumers that eat a variety of foods have a better chance of survival. Arctic ground squirrels, normally herbivores, sometimes eat bird eggs. Caribou, too, have been observed eating bird eggs and even lemmings.



Brown Bears Say Yes to Everything: Few tundra animals, however, are true omnivores, requiring both producers and other consumers for food. Brown bears are good example of omnivores. They eat plant roots and berries as well as ground squirrels, caribou calves, muskox calves, and carrion.

Mosquitoes Need Blood, Nectar: Mosquitoes are infamous for their abundance in lowland tundra where their hordes can torment humans and animals. Both male and female mosquitoes sip plant nectar as herbivores, but the female is omnivorous. She needs a blood meal from a warm-blooded animal to produce the eggs she will lay on the surface of any nearby water.

Detritivores Reuse and Recycle

The greatest number and variety of consumers in any ecosystem are the detritivores that eat dead things and waste materials. They are very important to the tundra because they return all the minerals stored in the food chains to the soil for reuse by tundra plants. Without detritivores, producers would soon run out of the minerals they need to make food.

Big and Small: Some well-known animals such as ravens are detritivores. But the most important detritivores are tiny, extremely numerous – and ignored. The most visible detritivores are tiny animals without backbones (invertebrates) – **enchytraeid worms**, **springtails**, **mites**, the **larvae** of many kinds of flies, and **nematodes**.

Soil Teems with Life: Near Barrow, Alaska, scientists found the following invertebrates in an area of 1.09 square yards (1 square meter):
50,000 to 5 million nematodes
10,000 to 100,000 enchytraeid worms
10,000 to 80,000 mites
24,000 to one half million springtails
40,000 rotifers
15,000 tardigrades
700 fungus gnat larvae
smaller numbers of other insect larvae
Nearly all of these lived within 2 inches (5 centimeters) of the soil surface.

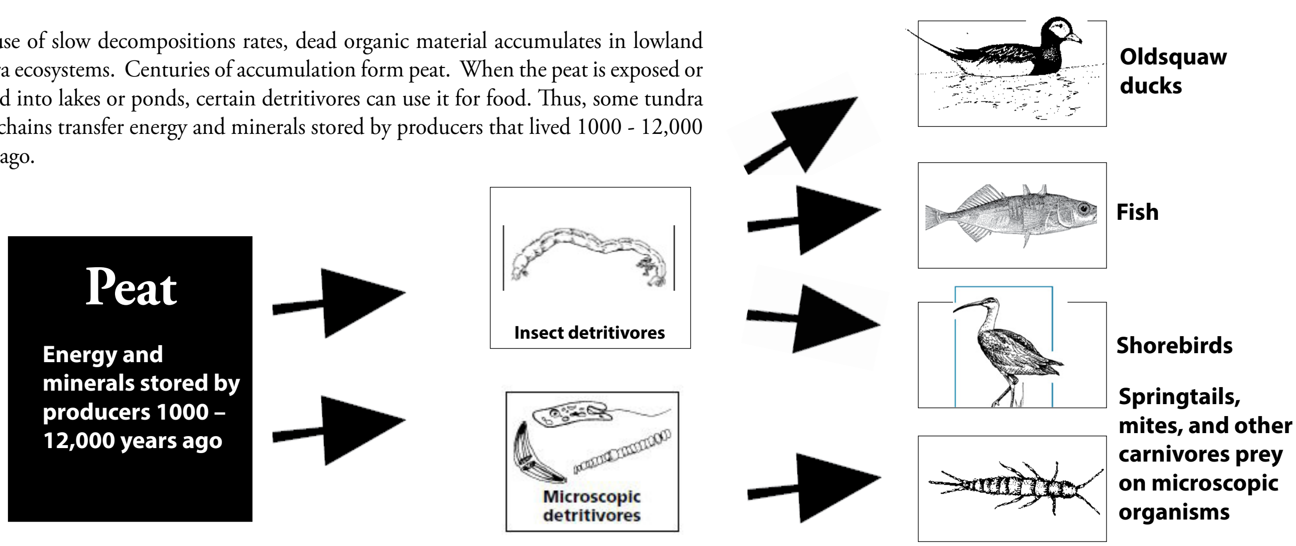
Too Much to Consume: These small animals eat much of the food produced by tundra plants. Despite their numbers, they cannot keep up with task of digesting all the organic material, especially under the rugged climatic conditions of the tundra.

More Detritivores: Completing the digestive team are **fungi**, **monerans**, and **protists** (see I*NSIGHTS Section 3* for descriptions in "*Five Kingdoms of Tundra Life*"), non-animal detritivores. In tundra, fungi are more important and more prolific decomposers than are the microscopic bacteria of the monerans and protists. Fungi are well adapted to acidic soils. The majority of monerans and protists are detritivores and, although not as active under tundra conditions, play a role in creating soil.

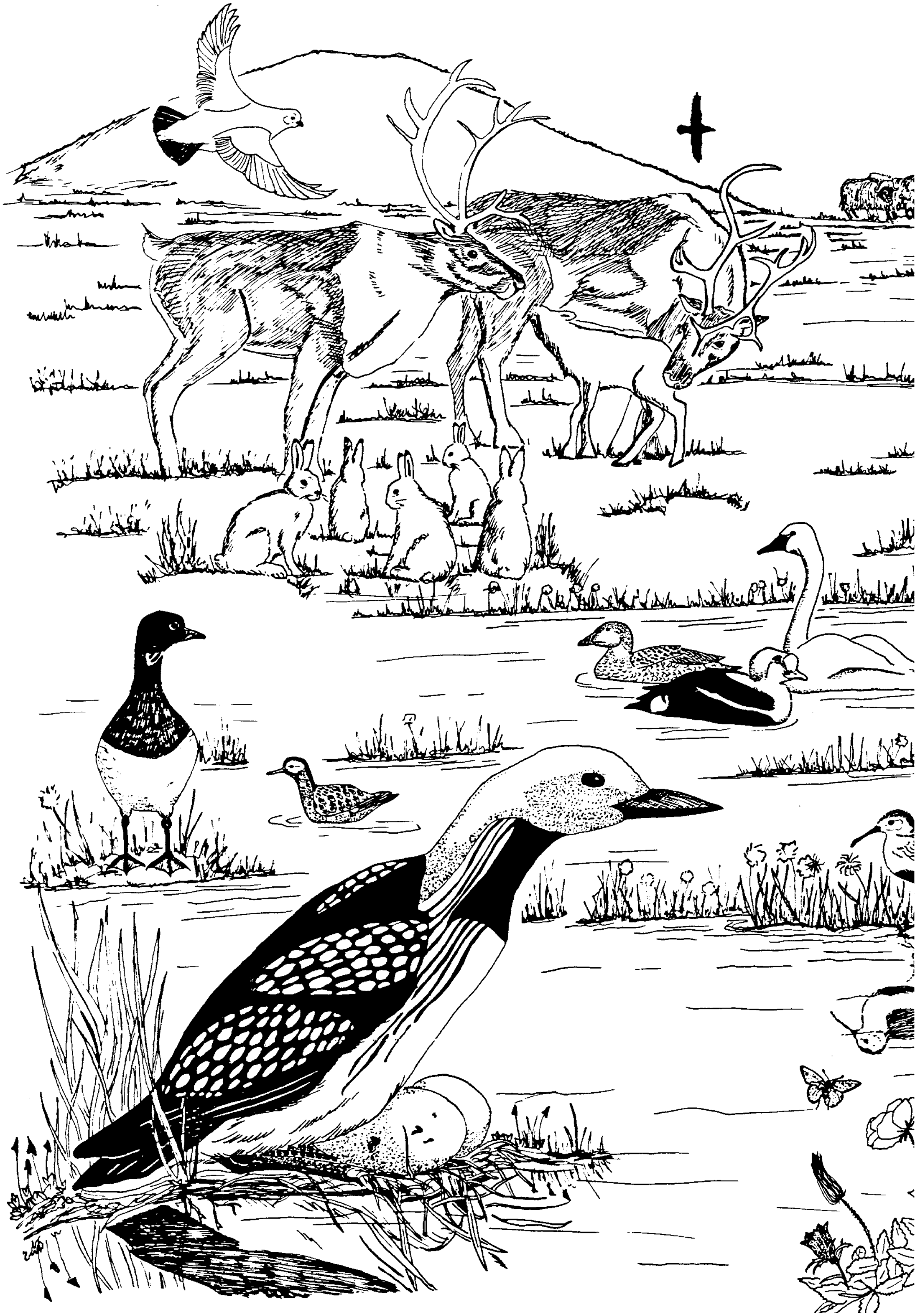
Tundra Dilemma – too cold to rot

All the work of tundra detritivores is limited by the climate and the environmental conditions. Living in the top 2 inches (5 centimeters) of soil or on the surface, they are

Because of slow decompositions rates, dead organic material accumulates in lowland tundra ecosystems. Centuries of accumulation form peat. When the peat is exposed or eroded into lakes or ponds, certain detritivores can use it for food. Thus, some tundra food chains transfer energy and minerals stored by producers that lived 1000 - 12,000 years ago.

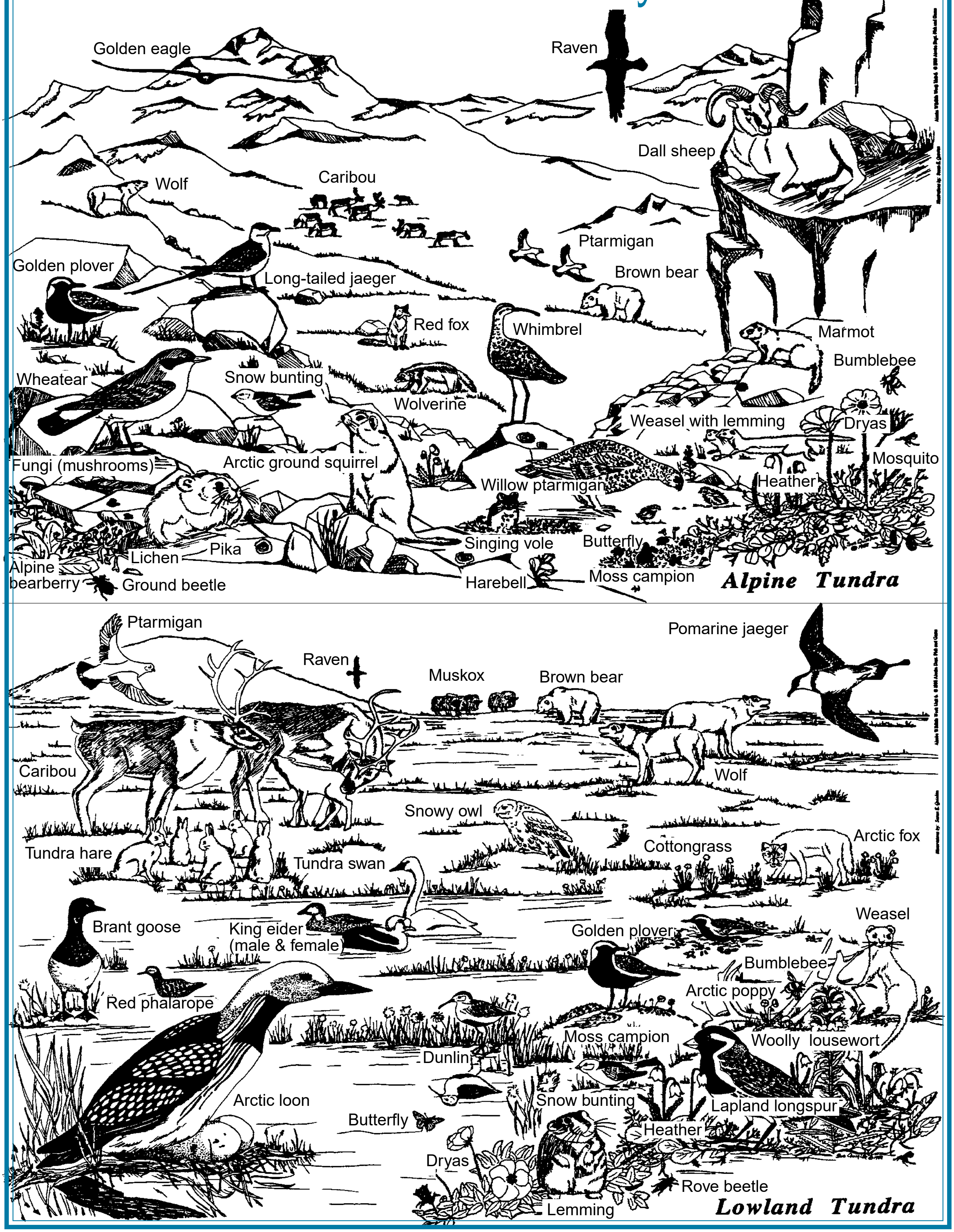



Sue Quinlan
© 1988
Alpine Tundra



Lowland Tundra

Tundra Poster Key



chilled from below by the permafrost and can be active only during the few short summer months.

Tundra detritivores do not break down all the new material produced each year. This slows the flow of energy and minerals through the ecosystem and limits tundra productivity. Much of the nitrogen, phosphorus, and calcium that could be returned to the soil for use by producers remains in accumulated detritus. This impoverishes the soil and, in turn, limits the growth of many tundra producers.

Detritus Food Chains

Dead, partially decayed material, called **detritus,** accumulates in tundra ecosystems. In alpine tundra, wind and water erosion carry away much of the excess. But in flat areas of lowland tundra, particularly in the Arctic, centuries of accumulation have created thick layers of detritus called **peat** – a storehouse of energy and minerals.
Many tundra food chains are based on dead organic material in ponds, lakes, and exposed peat.

Although detritivores break down waste materials and return energy and minerals to the nonliving surroundings, they incorporate some of the food (energy and minerals) they consume into their bodies. Many carnivores, including certain insects, ducks, shorebirds, and fish, get the energy and minerals they need by feeding on detritivores.

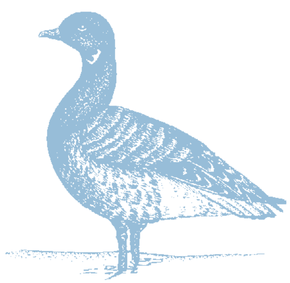
Essentially, these consumers are living off energy and minerals stored by tundra producers in the past. If peat layers have been exposed or eroded into lakes, the consumers in peat-based food chains are actually supported by producers that lived 1000 to 12,000 years ago!

Community Interactions – competition and symbioses

The tundra food web previously described portrays life and death relationships in the tundra ecosystem, but there are other equally influential relationships that do not involve eating the next in line. **Competitive relationships** occur within and between species. The term **symbiotic relationships** (literally *"living together")* describes three forms of tundra neighborliness: **mutualism**, **commensalism**, and **parasitism**.

COMPETITION – I can grow faster

Competition occurs when the supplies of food, water, shelter, and space are limited. Any plant or animal that can get more water, more minerals, more energy, more space, or better shelter than its neighbors will grow healthier and leave more offspring.



Competition in All Sizes: All living things compete with similar organisms to one degree or another. Herbivores such as caribou or lemmings eat the same kinds of plants and compete with one another for available food. Birds (such as geese) need safe nesting sites and compete with one another for the best. Competition is a constant interaction.

The Losers are Gone: Competition is often easiest to see in retrospect. For example, when we look at the plants around us, we see the results of past competition for water, minerals, and access to sunlight. The winners remain, and the losers die. To observe competition in action, biologists (and students) must make many observations of the competing organisms over a period of time.

MUTUALISM – the friendly symbiosis

Species or organisms benefit from the symbiosis of mutualism. In the tundra ecosystem, lichens provide an excellent example of two species benefiting from their association.

Complementary Traits: Lichens are actually a combination of two organisms: a fungus and an alga, or cyanobacteria. The alga, capable of photosynthesis, manufactures food for itself and for the fungus. The fungus stores water and provides a shell that protects the alga from drying in the wind. In some cases, the fungus may also help the alga obtain nutrients from rocks, soil, or rain water by excreting acidic fluids that break down the rock surfaces.

Pollinators: Although the wind helps to pollinate some tundra plants (sedges and cotton grass, for example), plants that are less common or grow only in specific sites rely on insects to ensure successful pollen exchange. About 90 percent of alpine and more than 60 percent of arctic tundra flowers are insect-pollinated, mainly by bumblebees, butterflies, moths, mosquitoes, and other flies.

Seed Carriers: Berry-producing plants have a mutual relationship with berry-eating animals that carry their seeds.

Fungi Aid Plants in Mineral Absorption

Fungi called **mycorrhizae** seek out the roots of plants and then grow around or even into the plant's fine root hairs. At one time, scientists thought these fungi were harming the plants. Instead, they actually help plants obtain minerals from the soil.

The fungi benefit from the association when the plants pump sugar made in their leaves down to their root hairs. This provides energy for the fungi. More than 90 percent of the plants in Alaska, including all our trees and berry-producing plants, could not grow without these mycorrhizal fungi. Many of the mushrooms we see are the fruiting bodies of mycorrhizal fungi.

Moneran Bacteria Help Release Nitrogen

Another important mutualistic association occurs between certain plants and monerans. Plants must have nitrogen in order to grow, but they are only able to use nitrogen that is in the soil. Most of the nitrogen on earth is in the air, making it useless to plants.

Microscopic bacteria known as "nitrogen fixers" take nitrogen from the air and convert it to a form that is usable to the plant. In exchange, the plant provides the bacteria with the sugars it needs. This symbiosis allows the plant to grow on poor soil where most other plants cannot survive. And the plant-bacteria combination improves soil conditions for future plant growth.

COMMENSALISM – no harm done

In commensalism, another form of symbiotic association, one species benefits while the other is neither helped nor harmed.

Looking for Scraps: Arctic foxes scavenge food from the kills of wolves, brown bears, and polar bears. Although the larger predators are unaffected (they don't miss the scraps), the foxes benefit from food that they could not obtain on their own.

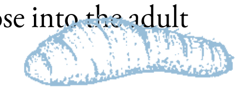
Nest Guardians: Golden and black-bellied plovers nest on high spots on the tundra – frost boils, pingos, and ridges. Both the male and female plovers guard their nest and keep sharp watch for predators. Whenever they spot a danger, plovers whistle loudly to warn the nesting mate.

Scientists have observed that other smaller shorebirds nest near plovers and react when the plovers give an alarm call. By nesting near a plover, these birds gain a sharp-eyed guard for their own nests.

PARASITISM – a win-lose situation

In the third type of symbiosis, parasitism, the parasite benefits and the host is harmed or eventually killed. Parasites fulfill useful roles in the tundra ecosystem by helping prevent plant and animal population explosions and by contributing to the natural cycle of life and death.

Caribou Tormentors: Caribou are hosts to a number of parasites. The warblefly lays its eggs at the base of caribou hairs. When the eggs hatch, the larvae burrow into the caribou's skin and feed on its subcutaneous tissues. In June, when the larvae reach a certain size, they burrow out through the caribou's skin and drop to the tundra, where the larvae pupate and metamorphose into the adult warblefly.



The warblefly larvae benefit from the food and shelter provided by the caribou, but the caribou is weakened. Many kinds of parasites occur in tundra, including fungi and insects that parasitize plant roots and microscopic organisms that cause animal and plant diseases.

Less Diversity than Other Ecosystems

The sight of hundreds of migrating caribou is awesome and gives an impression of abundance in the tundra. It is a misleading picture.

The limited number of species is the real story of the tundra. *There are fewer species in tundra than in most other ecosystems.* This means that there is *less diversity* in tundra than in other ecosystems.

Climate Limits Diversity: As a rule, the number and variety of living things decrease as the severity of the climate increases. Fewer species of living things are found on northernmost tundra than are in the subarctic maritime tundra. Fewer species are found at highest elevations in alpine tundra than are near the **tree line**.

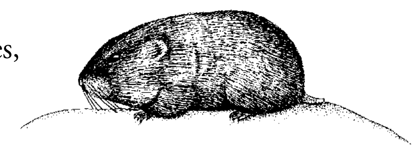
Balance on a Smaller Scale: Tundra ecosystems are sometimes considered simple, compared with other ecosystems, because they contain relatively few species of plants, animals, and other living organisms. Yet all kingdoms are represented and the relationships among them are just as intricate and finely balanced as elsewhere in the world. Small changes can radiate through members of the tundra community via food webs and symbiotic and competitive interrelationships.

POPULATION CYCLES

Quick Facts

Definition – Population Cycles: Striking changes in animal numbers that occur repeatedly and, in some cases, on a fairly regular schedule

Tundra Examples: Lemmings, voles, ptarmigan, crane flies, certain sandpipers, and perhaps caribou



Why? Scientists don't know! Plant-herbivore interactions, predator-prey interactions, and soil nutrient (mineral) recycling may be involved.

WHAT HAPPENS TO BROWN LEMMINGS?

Brown lemmings usually occur at low densities (one lemming per 125 acres [51 hectares]). Some summers, however, they become much more abundant (8 per acre). The population explosion happens in just one to two years, and the crash occurs in just one summer. Near Barrow, lemmings cycle every three to six years.

Fat Predator Hypothesis: Scientists first thought that lemming populations cycled as a result of predators. During the years when lemmings are abundant, predators such as weasels, foxes, snowy owls, and jaegers can raise more young, feeding them on all those lemmings. When lemmings are scarce, the owls and jaegers don't nest or fail to raise young. Other factors such as shallow snow cover make it easier for predators to kill more lemmings in some winters than in others.

Scientists have discovered, however, that all the predators and their young could not eat enough lemmings to account for the sudden crash in lemming numbers. **Predation is not the main cause of lemming population fluctuations**.

Mineral Starvation Hypothesis: Another hypothesis still being examined is the relationship between lemmings and the minerals available for plants. In the thin tundra soil, growing plants soon deplete the minerals to less than they require. Most tundra plants adapt to this scarcity and conserve their minerals. They store minerals in their roots during winter and pump them, along with newly absorbed minerals from the soil, into new leaves in spring.

Abundant, hungry lemmings upset that delicate conservation balance by removing more minerals (eating so many roots and leaves) than can be seasonally replenished. Short on minerals, the plants produce less nutritious leaves. Lemmings need a stable supply of calcium, phosphorus, and nitrogen to reproduce. **If the plants they eat contain few of these minerals, lemmings cannot produce many young.**

Lethal Combination: Low reproduction, combined with intense predation, could cause a rapid population decline for lemmings. After the crash, plants can rebuild their mineral reserves, eventually growing nutritious leaves and roots for the remaining lemmings. These lemmings produce more young and the population expands once again.

Debate Continues: Scientists still debate the relative importance of these and other variables. The answer, they agree, is in the link between lemmings and their environment.

Human Impacts on Tundra Ecosystems

Section 5
TUNDRA INSIGHTS

Global changes in human populations

Until the mid-1800s, humans had little impact on high latitude tundra ecosystems because global population was small, technology was minimal, and the harsh living conditions kept out most but the indigenous people who had evolved in the tundra environments. In Alaska, for example, the **nomadic** Inupiat, Yup'ik, Aleuts, and some Athabaskan peoples moved with the seasons. None lived full-time in alpine tundra environments.

As human populations around the world increased and technology enabled human desire and ability to develop resources, tundra regions were no longer isolated from change. Waves of explorers, fur trappers, traders, and missionaries moved into tundra regions of Alaska.

Local Extinctions: Among the first to be **extirpated** was the muskox, the last herd of 13 shot for food in 1865 by whaling and exploration parties. The animals' defensive maneuver of circling to face predators was adapted to wolves, not rifles. (Muskoxen were successfully reintroduced from Greenland in the 1930s and again now roam Alaska's northern and western tundra environments.) Other species, including the Steller 's sea cow and speckled cormorant, became extinct.

Centralization: The nomadic way of life of the indigenous peoples became another casualty as these people were encouraged to live year-round in villages and to send their children to mission schools, thus concentrating human use of land and wildlife resources to areas within traveling distance from villages.

TECHNOLOGICAL DEVELOPMENTS

In the last century, technological developments in transportation, housing, clothing, and communications have made living in tundra environments more feasible for a greater number of people.

Changing the Odds: Tools for securing food from the land have dramatically changed – rifles, snow machines, four-wheelers, boat motors, and aircraft all make hunting easier and more effective than even a few decades ago.

Industrial Migration: Now resources can be extracted on a huge scale in tundra environments once thought to be too forbidding. The Red Dog zinc mine, the North Slope oil fields, and the trans-Alaska oil pipeline are Alaska examples of how far technology advanced to permit industry to operate at high- latitude tundra locations having extreme environmental challenges.

MPACTS FROM DISTANT SOURCES

Ironically, some of the most pervasive influences on high-latitude tundra ecosystems are coming not from on-site industry, but from cities and industries half-way around the world. A "soup" of pollutants released into the air in Europe and Asia is transported northeasterly by arctic air masses directly across the polar region to Alaska and Canada. The result is **arctic haze**, **acid rain**, and in some cases **radiation** fallout.

Arctic Haze

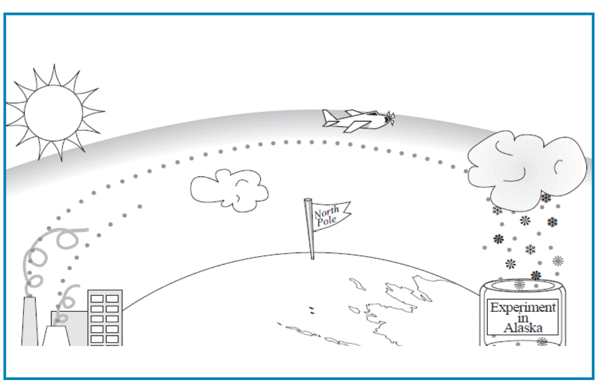
As recently as 1972, scientists still believed that the air in the Far North was pristine, the clearest and cleanest in the world. Wrong.

Alaska Discovery: A scientist from Alaska's Geophysical Institute found that the air was laden with industrial particles. The quantity of particles reduced by 30 percent the amount of solar radiation reaching the ground at noon on April days. That can make Alaska skies as dirty as the air above some parts of California.

The reddish-brown of arctic haze that affects about 9 percent of the globe was observed and named in a 1957 report by a U.S. Air Force officer stationed in Alaska.

Chemical "Fingerprint." The murky bands of black soot, sulfuric acid, and industrially produced organic compounds tend to stay aloft from winter through early spring, trapped in the stable arctic air mass with little snow to wash the particles out of the air. Chemical "fingerprints" of the particles identify sources in Russian, western Europe, and, in spring, eastern North America.

Dissipates in Spring: So far, spring precipitation and changing air movements seem to dissipate the haze without ill effect. Snow above the Arctic Circle is still clean, meaning that the chemicals are falling to earth elsewhere, probably farther south.



Acid Rain Potential

Arctic haze can contribute to acid rain. Acid rain is rain that is more acidic than normal. It forms when raindrops or snow fall through layers of air pollution such as that in arctic haze.

Fossil Fuel Particulates: Particulates from the burning of fossil fuels (oil, coal, and gas) react with water and oxygen molecules. Sulfur dioxide and nitrogen oxide particles become sulfuric acid and nitric acid.

Far from the Source: Acid rain can be deposited hundreds and even thousands of miles from the source of its pollutants. Particulates can also be deposited dry to add to the future acidity, but those sources are usually local. Too much acidity can kill sensitive plants and change lake environments. Fish habitat and forests in Canada, northeastern United States, and Europe have been hardest hit.

Lichens – Early Warning System: So far, Alaska has experienced little acid rain. Tundra environments would be the first to show signs of stress because of the dominance of lichens – an organism so sensitive to air pollution that it could be called sort of a "canary in the coal mine."

Lichens Absorb Air Pollutants First: Lichens, a symbiotic partnership of algae and fungi, absorb moisture and nutrients directly from the atmosphere through their surface cells. (See I*NSIGHTS Section 2* for further details on these amazing organisms from the fungi kingdom.) Thus, they can accumulate the spectrum of airborne elements, from healthy nutrients to pollutants.

Serious Consequences: Acid rain has two serious consequences for lichens. Sulfur dioxide and nitrogen dioxide – whether dissolved in water or in particle form – interfere with the functioning of the chlorophyll molecules in algae, thus preventing photosynthesis. Unable to make their own food, algae and their dependent fungi die.

In addition, acid rain acidifies the substrates – soil, rocks, and wood – on which lichens grow. Because lichens are unable to grow on acidic surfaces, acid rain also can prevent lichen growth and establishment.

Radioactive Accumulation

Lichens also absorb and accumulate radioactive fallout far more than can vascular plants and then pass them along in the food chain. The short tundra food chains do not provide opportunities for the substances to be diluted among many consumers as they would be in more complex food webs. Because many tundra food chains are anchored by lichens, the entire ecosystem can be impacted.

Chernobyl and the Sami People: Months after the Chernobyl nuclear power plant explosion in 1986, the reindeer herded by the Sami people of Scandinavia were found to be contaminated with radioactivity. Cesium 137 (half-life of 30 years) and other radionuclides released in the explosion and carried in the air had rained down on their tundra grazing areas.

Lichens absorbed the radionuclides, and reindeer ate the lichens. Thousands of the reindeer had to be destroyed, a devastating impact to the traditional culture and way of life of the Sami people. Examples like this raise concern in Alaska.

IMPACTS FROM LOCAL SOURCES

Let's look more closely at Alaska and environmental challenges for humans living in tundra ecosystems.

Pollution

Combustion fumes from engines in cars, planes, four-wheelers, and snowmobiles and from home heating and industry can affect lichen growth and health. Lichens often disappear downwind from sources of local air pollution.

Vehicles on Tundra

Permafrost forms the foundation of about 85 percent of Alaska. In much of northern and northwestern Alaska, **permafrost** lies within two feet of the soil surface. The challenge is to keep that ground frozen. Otherwise, everything above it changes, whether it is the landform, vegetation, animal life, or the structural integrity of any human structures built there.

Removal or destruction of tundra vegetation by vehicle traffic reduces the **insulation** protecting the soil and allows melting of the permafrost.
Slumping, Freeze-Thaw Expansion: In wet soils, when permafrost melts, the ground slumps, creating a depression. This depression fills with water during summer, and vegetation adapted to drier sites is flooded. In winter, the collected water freezes and expands, pushing surrounding soil up and out. Through repeated freezing and thawing, along with the eroding effects of wind and water and destruction of plant cover, the depression grows larger each year.

Vehicle ruts may be a significant impact in tundra. They create mudholes and bogs caused by permafrost melting. In addition to natural melting at the original site of damage, the impact is further impacted as drivers drive around these newly created bogs to avoid them.

Centuries to Recover: Organic matter may accumulate for many centuries before the soil will be insulated enough for permafrost to redevelop. Only then will the tundra vegetation return to its predisturbance condition. Human activities such as driving four-wheelers, snowmachines, or trucks over the tundra create long-lasting and strikingly visible scars on the land (see photographs in *Insights Section 2).*

Engineering Solution?

Engineers have now developed a way to prevent melting the tundra permafrost. They leave tundra vegetation intact while piling 2 feet (.61 meter) or more of gravel on top of it to provide insulation below road surfaces and buildings.

Some Side Effects: This method prevents permafrost melting, but causes other changes in the tundra. Gravel dust that blows from the pads and roads alters snowmelt patterns in surrounding areas. Gravel road beds and building pads superficially resemble **high-center polygons** and **frost boils** (see INSIGHTS *Section 2)*, and are sometimes used by animals that prefer dry tundra.

Tundra plants cannot invade the gravel piles for many years, however. Until they can, these sites do not provide the same camouflage or food supplies that natural dry tundra sites do.

New Flooding: Additionally, gravel road beds and building pads interfere with the natural flow of water across the tundra. Water backs up along the upstream side of the roads and floods formerly dry sites. The permafrost melts and new depressions and ponds are created. An area of tundra much larger than just the roads or pads changes.

Much of the tundra in northern Alaska is underlain by permafrost. Removal of vegetation reduces the insulation protecting the soil and allows melting of the permafrost. When permafrost melts, the ground slumps, creating a depression that grows larger each year.

Gravel Source Conflicts: The gravel used for roads and pads must be excavated from nearby river beds and gravel banks. The extraction of gravel can affect water flow, turbidity, and other physical characteristics of rivers, upsetting fish migration and spawning. Excavation also removes large areas of streamside habitat that are important for caribou, muskox, ground squirrels, birds, and other organisms.

Harvesting Tundra Wildlife

Mortality Factors: Humans kill animals for food, furs, sport, protection of life and property, and by accident (*with vehicles on roads, for example*). Animals are also killed by other predators and die of disease, starvation, and injuries.

Any population of wildlife will decline if more animals die than are born. If more are born than die, their population is considered **sustainable**.

Slow Maturity: Because most tundra animals are slow to mature and produce fewer young relative to similar animals in milder environments (see "Examples of Slowly Maturing Wildlife" on page 62), the harvest of tundra animals by humans needs to be done with care to avoid overharvesting.

Wildlife Agencies Monitor Wildlife and Hunting

Wildlife agencies oversee human use of tundra fish, birds, and mammals. Based on field observations and research, which determine population trends, regulations are set annually. By taking only from the excess, hunting is regulated so that a wildlife population is sustainable.

Management Tools: Harvest regulations usually include two tools: **(1) Bag limits** are the maximum number of animals of any one species that a person may take in one area. **(2) Hunting seasons** limit the time that a species may be harvested in a particular area. For example, ptarmigan hunting might be open from August to April in a certain area. Current regulations are available on the Alaska Department of Fish and Game website.

Seasons – Time Out to Multiply: Wildlife managers recommend limited hunting seasons for two reasons:

(a) Fewer animals can be taken in a shortened season than if hunting were allowed year-round.
(b) Hunting seasons are generally closed during the spring so that animals can produce young and increase population. If a pregnant animal is harvested in the spring prior to giving birth, then not only is one animal lost from the population, but all her potential offspring as well.

Hunting seasons tend to be set during the fall, after most animals have given birth and raised their young. Fall seasons are also more practical: cooler temperatures reduce decomposition of meat while it is being transported from the field.

Expanded Seasons When Warranted. When an animal's population is high, seasons and bag limits may be expanded. The Western Arctic Caribou herd, for example, grew to a high level such that the season on bulls was open year-round without overharvesting the herd.

Boards Set Harvest Rules

Harvest rules for mammals and fish are set each year by the Alaska Board of Game and the Alaska Board of Fisheries. *The members of these boards are nonpaid citizens appointed by the governor, and approved by the legislature*.

Public Participation in Rulemaking: All Alaskans have an opportunity to have their say about hunting, fishing, and trapping regulations. While Alaska Department of Fish and Game biologists make recommendations to the boards, the board members also hear testimony from local advisory boards and citizens before making decisions that allocate fish and wildlife harvest. (*See accompanying flow chart for the Board of Game and Board of Fisheries.)*

Similarly, the U.S. Fish and Wildlife Service sets rules for harvest of migratory birds based on local and state input.

DEBATE – FRAGILE OR RESILIENT?

Compared with other ecosystems, tundra food chains are short, and the food web is simple. Fewer species of plants, animals, and other living things dwell here.

Low Diversity: This lack of diversity has led some scientists to conclude that tundra ecosystems are *more fragile* than other ecosystems. It has led other scientists to conclude that tundra ecosystems are *more resilient.*

Domino Effect of Changes

Those who consider the tundra to be fragile point out that, because there are few interconnections, changes in any single plant or animal population are likely to affect the entire ecosystem. These ecologists argue that human activities that affect one tundra species also affect other species.

One study suggests that the dust created by traffic on dirt roads in the tundra changes the plant life and herbivores found near the road. Another study suggests that increased oil-field activity in the Arctic has changed the patterns of caribou migration.

Success in the Face of Adversity

Ecologists who consider tundra ecosystems more resilient than other ecosystems cite the population fluctuations that occur naturally, the ability of such key tundra wildlife as lemmings to reproduce rapidly, and the continued abundance of many tundra birds despite frequent years of nesting failure.

These scientists think that, because radical changes in animal and plant populations and production occur regularly, tundra ecosystems have greater ability to absorb changes than do other ecosystems.

Agreement on Cautious Use

Most scientists do agree that we must be cautious in our use and development of tundra resources. Low productivity, ease of animal harvesting, slow decomposition rates, unstable permafrost soils, and lichens' sensitivity to air pollution are points that are often raised.

For many people, the vastness of lowland tundra enhances its beauty and wilderness value. Others feel that, because the tundra covers such large areas, human activities do not have a significant impact on the tundra ecosystem.

Who's Right?

To an extent, both viewpoints are correct. Research is ongoing to monitor changes and understand the tundra more fully.

Large Home Ranges: Almost all tundra wildlife is forced to use large areas just to obtain adequate food. The great caribou herds wander over thousands of square miles, gazing intermittently as they travel. Even when a large herd has passed through an area, many ungrazed patches of food remain for the future.

To stay close to their prey, their predators, the wolves, adopt

EXAMPLES OF SLOWLY MATURING TUNDRA WILDLIFE

BROWN BEARS living on the tundra of the Brooks Range do not usually breed until they are eight or nine years old, and then they give birth to young only every four to five years. In contrast, brown bears living in the more productive forests of southcoastal Alaska begin breeding when half that age and can produce young more frequently – every three to four years.

CERTAIN TUNDRA BIRDS may lay more eggs than related species in milder environments, but fewer of their young survive to maturity. They don't get a second chance to nest if the weather delays them or predators eat their eggs. Complete nesting failures are common. Also, they suffer high mortality during their long-distance migrations.

LARGE FISH in some tundra ponds were discovered to be 40 years old or older. Fish of the same species in temperate regions reach the same size in only 10 years. Tundra fish may not begin reproducing until 10 years old, and then they produce fewer eggs than do fish in other environments.

the same wandering strategy. Tundra brown bears have home ranges of 100 to 400 square miles. Even fairly small birds such as golden plovers defend territories measured in many acres to give their young the best chance of surviving.

Other nomadic tundra wildlife such as snowy owls, jaegers, and arctic foxes require large areas of tundra because the conditions they need for successful reproduction or winter survival do not occur at any single location.

Low Densities of Wildlife

Consequently, the densities of birds and mammals are low throughout much of the tundra expanses during the year.

Although buildings, airports, roads, and other human constructions may permanently change large areas of tundra and affect tundra wildlife, the actual number of animals displaced by individual projects is small.

Times of Concentrated Use

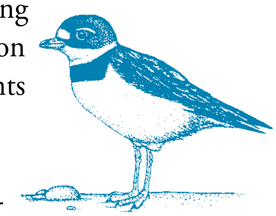
At certain critical times and places, however, tundra animal populations concentrate to take advantage of limited resources. Disturbance to these sites may have serious consequences.

For example, tens of thousands of caribou gather in relatively small **calving** grounds and areas for insect relief during summer. Thousands of geese converge on large tundra lake systems to **molt**. Hundreds of thousands of waterfowl and shorebirds congregate to feed in productive coastal and dry tundra areas prior to fall **migration**.

These impressive numbers reflect *the vastness* of the tundra more than *its productivity*.

No Space, No Nest: Nesting birds space themselves throughout available nesting habitat. Those unable to find an appropriate nesting territory simply do not nest.

Caribou Starve on Limited Range



Herds of caribou could not survive long in a small tundra area. They would soon overgraze the lichens and other plants and would die from lack of food.

That happened on St. Matthew Island, a tundra island and national wildlife refuge in the Bering Sea. A herd of reindeer (domesticated cousins to caribou) were released in 1944 to feed World War II military personnel stationed there. The humans left in 1945, and the herd increased to 6000 by 1963. Within a year fewer than 50 animals survived, and by 1983 the last one had died.

REFLECTIONS ON VASTNESS

Cumulative Effects: Alaska's tundra areas seem immense and secure in their vastness. The components of tundra ecosystems evolved to best survive in this vast space and isolation. Thus, it is important to look at the cumulative impacts of *all* the human interruptions in the ecosystem, whether buildings, roads, other infrastructure development, or uses.

Changes to Tundra are Long-Lasting: Tundra plants and animals recover slowly. Areas disturbed 50 years ago still have not returned to their original states.

Although individual projects have relatively little impact, the total of many projects that reduce available habitat, conducted over many years or decades, can reduce waterfowl, shorebird, and caribou populations in Alaska's tundra ecosystems.

Dealing with Differing Viewpoints

Controversy is pervasive, even valued, in a democratic society. Controversy occurs when a person's or group's ideas, conclusions, theories, or opinions are in opposition to those of another person or group.

The study of controversial subjects is essential to the education of all citizens in a free society. In preparation for contributing to a healthy society, students must learn to gather and examine evidence; differentiate opinion, fact, and inference; evaluate differing viewpoints with objectivity; and define and justify their personal points of view.

By stressing the use of facts to justify decisions, the importance of developing alternatives, and the use of appropriate problem-solving skills, teaching about controversial issues can impart real "survival skills" while bringing relevancy to the classroom.

What is controversial in one place and time may not be in another. In Alaska, wildlife-related topics are often controversial. As a state, our identity, tradition, heritage, and economy are linked to wildlife. Although most school curriculum is built around activities that present factual, non-controversial information, there are some topics and activities that are potentially controversial within Alaska communities. Rather than avoiding these topics, we encourage you to use the following guidelines.

Curriculum Selection & Lesson Preparation:

- Determine whether a specific issue is grade-level appropriate and relevant to the student.
- Choose issues that relate directly to the curriculum being studied and to the goals and objectives of this unit of study.
- Determine whether enough factual information can be gathered on the various points of view related to an issue.
- Be clear about what alternative positions will be presented in dealing with a controversial issue.
- Decide on your own opinion or position on the topic so that you can recognize your own biases.
- Use community resources and expertise, making sure that you choose people and materials to present more than one side of an issue, while being sensitive to differing cultural values in your presentation and selection. Have students prepare questions for guest speakers.
- Design the unit to teach citizenship skills such as critical thinking, listening, decision making, and problem solving as well as loyalty to democratic principles.
- Use community resources to adapt issues for local relevance, while also presenting the "big picture".
- Examine curriculum content and topics for cultural bias and include cultural sensitivity and respect for diversity.

In the Classroom:

- Develop a climate of trust, respect, and openness to free inquiry in the classroom as well as respect for the student's right to privacy and right to hold opinions and perspectives, thus valuing the strength of diversity in our society.
- Distinguish between fact and opinion when analyzing issues.
- Teach students to identify value-laden language that reveals built-in biases in materials. Look for these biases with different perspectives – such as "timber harvest destroys wildlife habitat" versus "timber harvest alters wildlife habitat."
- Have students scrutinize their own values that determine their positions on an issue.• Have students gather information from as diverse an array of sources as possible.
- Determine if facts were left out or slanted because of the bias of the presenter or the materials.
- Teach students to raise questions that clarify the important positions in a controversy rather than to attack positions with which they do not agree.
- Recognize stereotyping and avoid the polarization

that results. People and groups should not be strictly categorized. Include multiple players in the same role in simulations. Have these players hold different opinions to break down stereotyping.

- Use additional information, community resources, and pointed questioning to assist students in 1) viewing differences in values and opinions as positive and 2) learning to disagree without degrading others. Emphasize that different points of view are not "right" or "wrong."
- Include activities such as simulations, role-playing, creative writing, music, and dramatizations. This will encourage students to take positions temporarily on issues that are different from the ones they currently hold in order to clarify the basis for differences. Have students explain how people within a group or a role could hold different views.
- Use realistic simulations and role-playing activities where compromise and tradeoff situations are likely.
- Ask students to evaluate the effects of decisions on future actions and problems.
- Include effects on different populations and aesthetic, social, cultural, and long-term economic costs and benefits in any cost-benefit analysis or identification of impacts.
- Be as politically and religiously neutral as possible on value sensitive issues, and clearly delineate your own opinions when presenting them.
- Work on finding agreement on controversial issues by using techniques such as nominal group approach or finding common words (in differing viewpoints).
- When possible, let students choose the topic or issue to be studied.
- Provide opportunities for students to make decisions and engage in actions dealing with the issue.

With the Community:

- Anticipate the controversial issue in the curriculum and inform parents about how the issues will be treated before they are introduced. Invite them to attend lessons on these topics.
- Be clear about the community values held, and be cautious when examining opposing ones.
- If criticized for including a controversial issue in your lessons, do not respond defensively or with anger. Discuss your goals and your methods with critics so they can appreciate your sensitivity to their concerns.
- Before teaching the unit, obtain the support of the school administrator.
- Teach about the "real world" with an emphasis on problem solving, critical thinking, and citizenship skills.

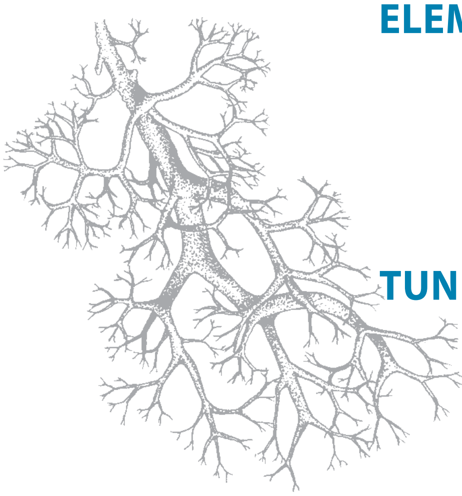
Text by the Alaska Department of Education with the Alaska Steering Committee for Project Learning Tree and the Alaska Resources Kit: Minerals, Teacher Advisory board.

Adapted from the Project WILD handout "The Teacher's Role in Dealing with Controversial Issues" by C.E. Knapp; the pamphlet "Curriculum Guidelines" by the National Council for the Social Studies; and a journal article in Environmental Education & Information, Vol. 3, #4, 1894, "The Handling of Controversy and Problem Solving in Environmental Education." Reprinted here by permission from the Alaska Department of Education.

TUNDRA ACTIVITIES

Section 1

ELEMENTS THAT CREATE TUNDRA



Section 2

TUNDRA TOPOGRAPHY AND SOIL

Section 3

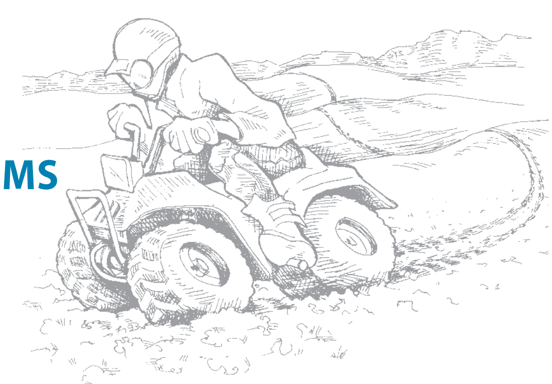
LIFE FORMS AND THEIR TUNDRA ADAPTATIONS

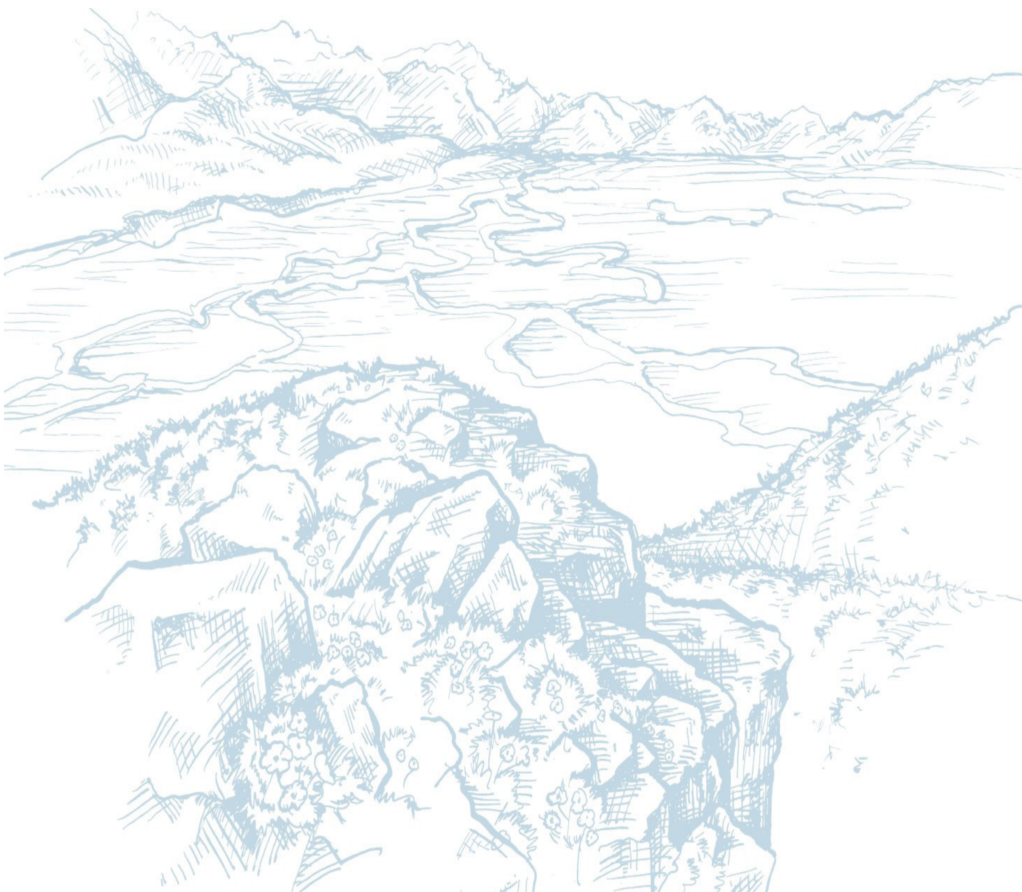
Section 4

TUNDRA ECOSYSTEMS – COMMUNITY CONNECTIONS

Section 5

HUMAN IMPACTS ON TUNDRA ECOSYSTEMS





Tundra Around the World

Section 1
TUNDRA ACTIVITIES

Grade Level: 4 - 12

State Standards: Geo A-1, Geo A-5, Geo B-1
NGSS: 4-ESS2-2., HS-LS2-2

Subjects: Science, social studies, geology

Skills: Using an atlas, reading maps, classifying

Duration: 45 - 60 minutes

Group Size: Individual, multigrade partners, or small groups

Setting: Indoors

Vocabulary: Biomes, limiting factors, tundra

Objective:
Students will map the distribution of tundra environments around the world.

Teaching Strategy:
Students use atlases and globes to identify where tundra is located around the world.

Materials:
Copies of an unlabeled map of the earth's continents or an enlargement of one on butcher paper; an atlas; globes; "Changes in Latitude" worksheet *(following pages)*.
OPTIONAL: "Biome Climates" worksheets *(following pages)*.

Background:
See *Tundra at a Glance* and *INSIGHTS Section 1, Elements that Create Tundra.*

Procedure:
1. Develop a class definition of **tundra** *(see Tundra at a Glance* and *INSIGHTS Section 1).* Correlate student definitions with dictionary, glossary, or encyclopedia definitions. Write the class definition on the board.

2. Using unlabeled maps of the world's continents for each student, locate and label the following: oceans, the equator, latitude lines in 10-degree intervals, names of all continents. Draw and label the longest rivers and the major mountain ranges on each continent.

3. Students look at vegetation maps for each continent or country, and color in the kinds of **biomes** (major plant communities) on each continent, using different colors to show tundra, forest, desert, and prairie.

4. Students use their maps plus a map showing political boundaries to make a list of countries in the world where tundra is located and determine which countries and places have the largest amount.

5. Students work in teams or as individuals to complete the "Changes in Latitude" worksheet. Test student learning by asking students to predict the elevation of tree line in an area and then to look on a vegetation map to see where tundra is located.

6. Ask students why there is more tundra in the northern hemisphere than in the southern hemisphere. *(Hint: Using a globe or a map, examine continent placement relative to the equator.)*

Evaluation:

Students present their maps to the class, pointing out the distribution of the planet's tundra regions. During their presentations, they give reasons why tundra is located where it is.

EXTENSION:

Compare climates. Compare tundra's climate to the climate of other biomes. Reproduce "Biome Climates" graph on following pages (five for each student) for the students to complete.

Curriculum Connections:

(See appendix for full citations)

Books:

Alaska in Maps: A Thematic Atlas

Arctic and Antarctic (Taylor)

Atlas of the World (National Geographic Society) or any other world atlas.

Biomes of the World – v.1 (Allaby), 7-12

Land Above the Trees: Guide to American Alpine Tundra (Zwinger), 9-12

The Arctic Land (Kalman)

Tundra (Kaplan)

Tundra (Sayre)

Tundra (Walsh-Shepherd)

What is a Biome? (Kalman)

U-X-L Encyclopedia of Biomes – v.3 (Weigel), 7-12

Media:

Arctic & Antarctic (Eyewitness Video)

Websites:

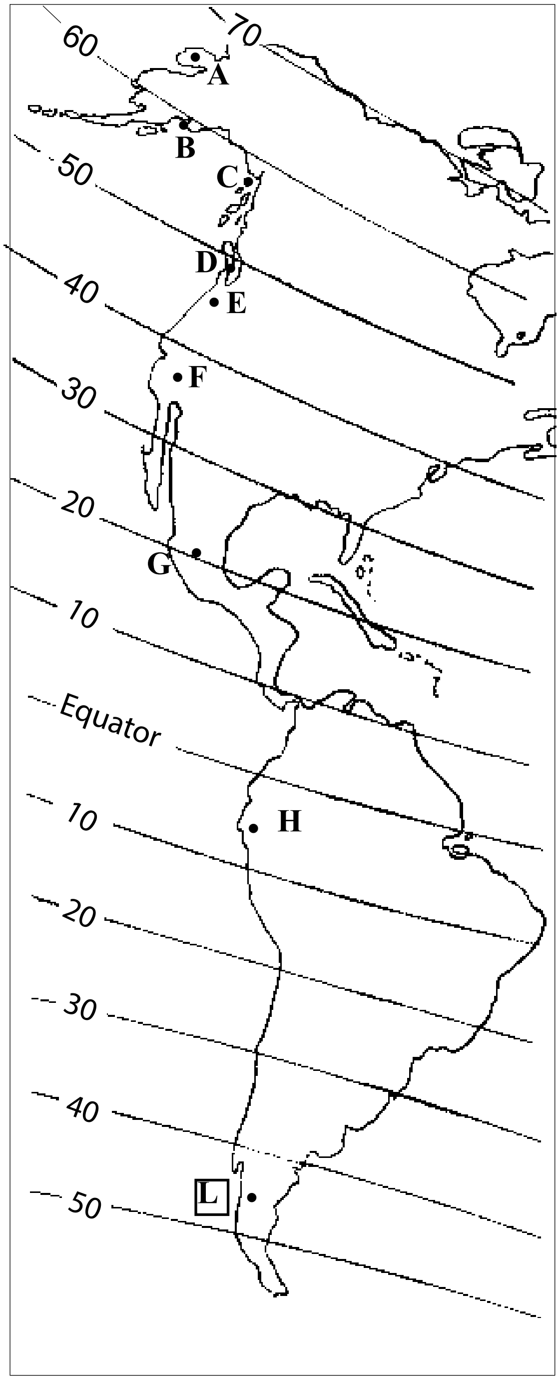
Various atlas websites: <www.maps.com> or <www.3datlas.com>

Teacher Resources:

(See appendix)

Tundra is even found at the equator – in Ecuador on Mount Cayambe, elevation 18,946 feet (5,775 meters).

Changes in Latitude Worksheet



Tree line is the environmental boundary between forest and tundra. A tree line occurs at the southern edge of lowland tundra in the northern hemisphere. Tree lines also occur on mountain tops around the world, at the lower edge of alpine tundra. Use the following data and the map to the left to make a graph comparing latitude and the elevation at which tree line occurs on mountain slopes.

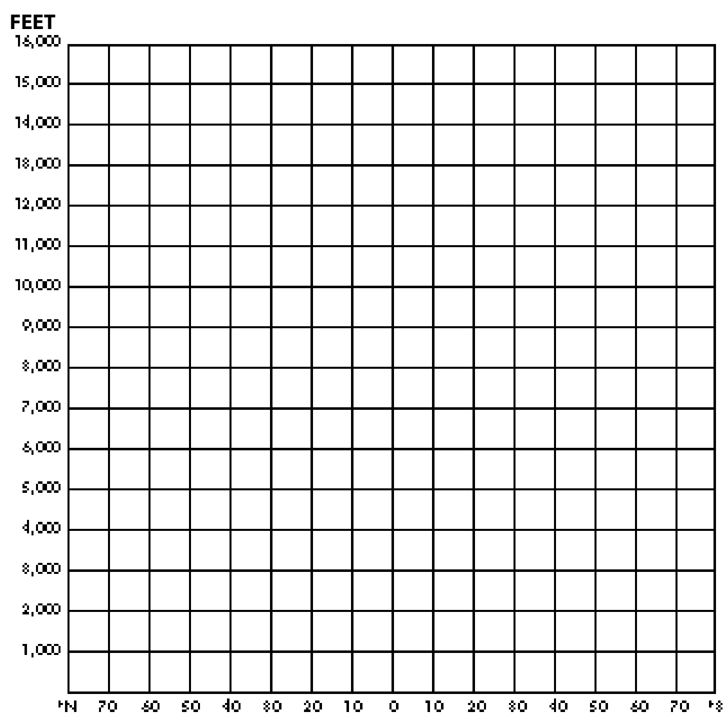
TREE LINE ELEVATION

Location	**Meters**	**Feet**	**Latitude**
A. Seward Peninsula AK	305	1,000	64.5°N
B. Turnagain Arm AK	533	1,750	61.2°N
C. Admiralty Island AK	610	2,000	57.5°N
D. Mt. Albert Edward BC	1524	5,000	48.3°N
E. Crater lake OR	1969	6,460	42.56°N
F. Mt. Whitney, CA	3243	10,640	36.6°N
G. Tapalpa, Mexico	4800	15,748	19.9°N
H. Chulucanas, Peru	4200	13,780	5.2°S
L. Mt. Maca, Chile	190	3,904	45°S

Based on your graph, use the following words in the following spaces to describe how latitude and the elevation of tree line are related:

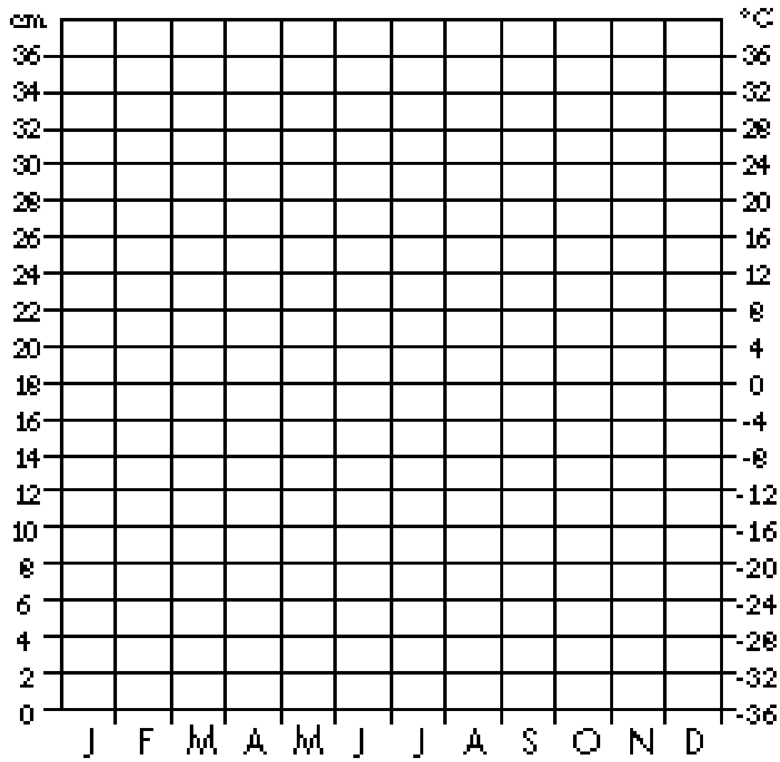
increases, decreases, higher, lower

1. As the latitude________________, the elevation at which tree line occurs____________.
2. In other words, alpine tundra occurs at ______________ elevations at high latitudes.
3. Locate your own town on the map, and estimate the elevation of tree line near you. Record it here:____________



Biome Climates Worksheet

Contact your local weather service, or use a library reference, to find out the average monthly temperature and precipitation for your area. If necessary, convert the temperatures into degrees Celsius and the precipitation measurements into centimeters. (°F - 32 x 5/9 = °C; 1 inch = 2.54 centimeters) Record these, and make a bar graph of the precipitation and a line graph of the temperature on the chart below.



My Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	___	___	___	___	___	___	___	___	___	___	___	___
Precipitation	___	___	___	___	___	___	___	___	___	___	___	___

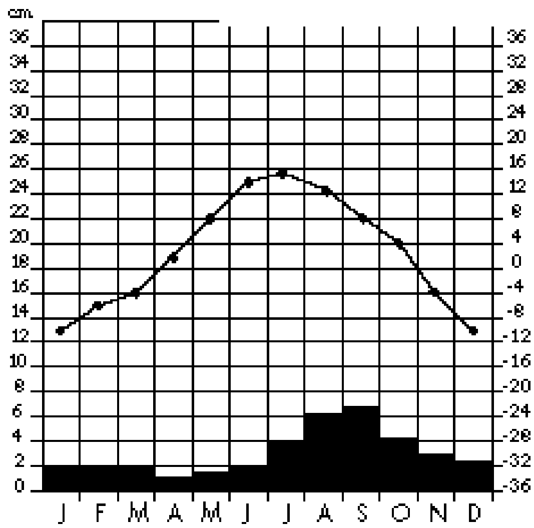
Location A	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-26	-28	-26	-18	-7	1	4	3	-1	-9	-18	-24
Precipitation	0.6	0.5	0.5	0.5	0.5	0.8	2.0	2.5	1.5	1.3	0.8	0.5

Location B	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-20	-20	-18	-11	-1	6	12	10	5	-4	-13	-20
Precipitation	0.6	0.8	0.8	0.8	1.0	1.3	3.8	5.1	3.8	1.5	1.0	0.8

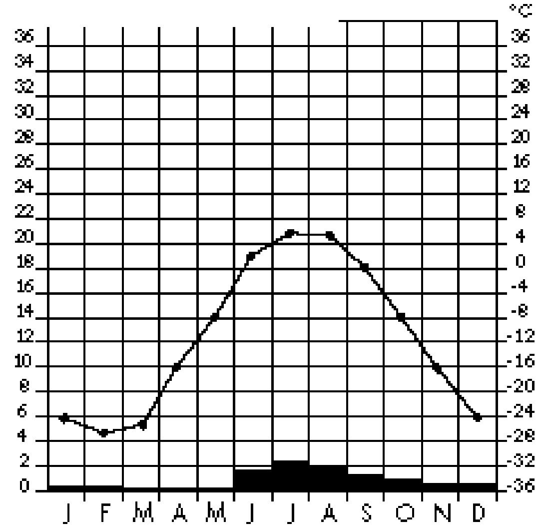
Location C	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-15	-13	-12	-4	4	11	13	11	7	-1	-8	-16
Precipitation	1.3	1.9	2.0	1.3	2.0	3.2	5.1	10.2	6.1	3.3	2.5	1.3

Location D	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-2	-2	-2	1	4	7	10	11	8	4	-4	-2
Precipitation	7.6	7.6	5.1	3.8	5.7	4.6	5.6	9.9	9.9	11.4	10.2	6.4

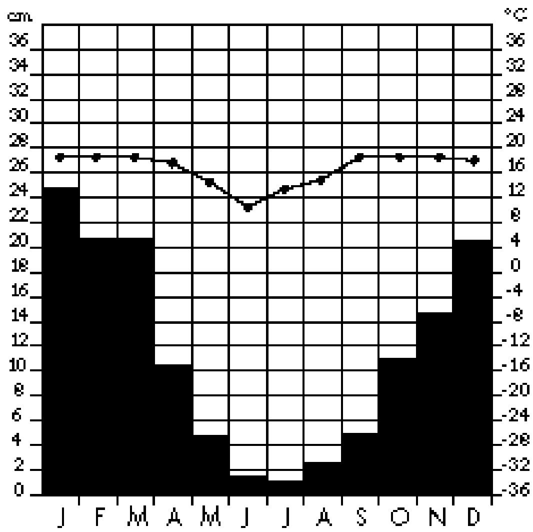
Biome Climates Worksheet



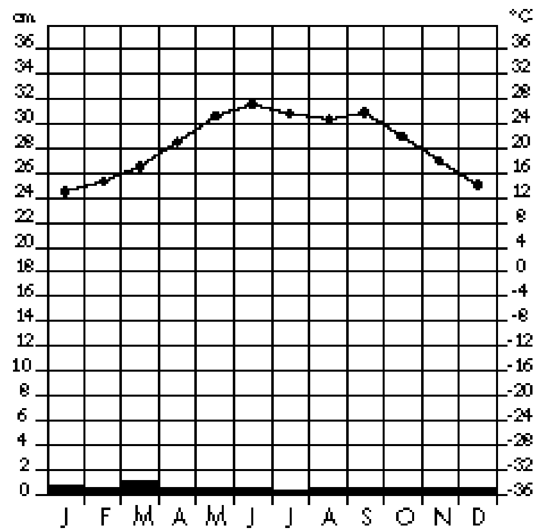
Boreal Forest: Anchorage, Alaska



Tundra: Barrow, Alaska



Tropical Forest: Cuiba, Brazil



Desert: Aden, Saudi Arabia

The climatographs above show the average temperature and the amount of precipitation for four biomes: tundra, boreal forest, desert, and tropical forest. Temperature is shown in degrees Celsius on the line graph; precipitation is shown in centimeters on the bar graph.

1. Which two environments are the driest? 2. Which are the wettest? 3. Which are the two coldest?
4. Which are the two warmest? 5. Which environments do not have cold seasons?

Make climatographs for each of the locations described on page 1 of this worksheet. Predict the type of biome found at each of them. (In general, trees cannot survive in environments without at least one month of temperatures averaging above 10°C [50°F]. Permafrost is most common in areas with a mean annual temperature below -4°C [25°F].)

Compare the climatograph you drew for your home area to the other climatographs.
To which of the climatographs that you drew is it most similar? How is it different?

6. After you have made your predictions, ask your instructor for the names of the four locations. Find each of these on a map. Were your predictions about the environment in each location correct?

The idea for this activity and some of the climate information is from University of Colorado, Biological Sciences Curriculum Study. Green Version, *High School Biology*, Rand McNally and Company, Chicago, 1968.

Worksheet Answers

BIOME CLIMATES WORKSHEET, page 72

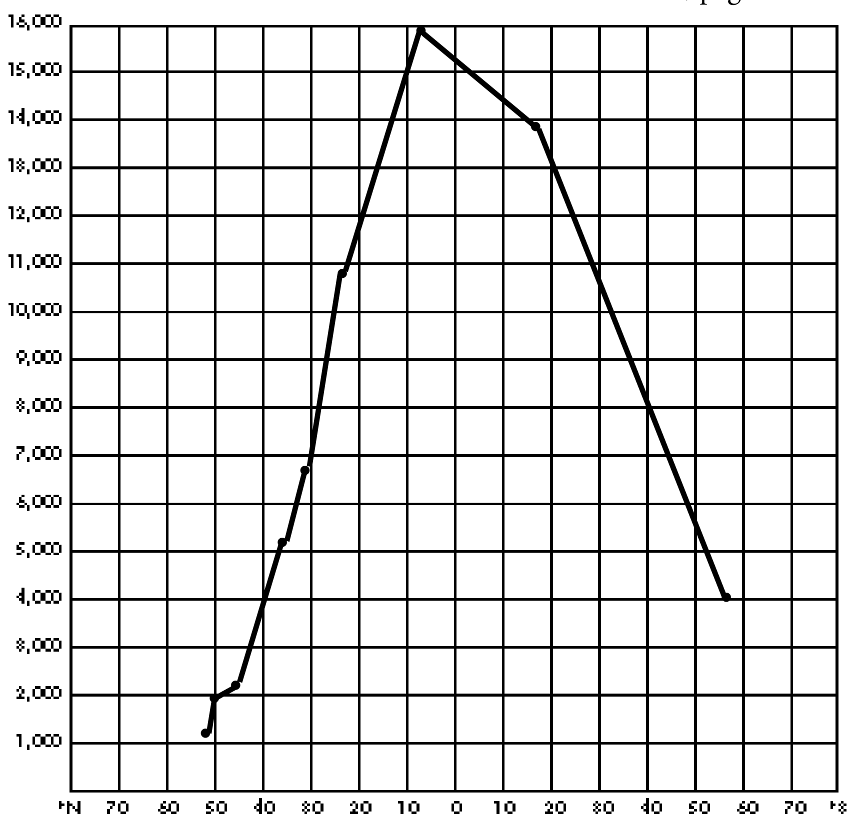
1. Driest: **tundra, desert**
2. Wettest: **tropical forest, boreal forest**
3. Coldest: **tundra, boreal forest**
4. Warmest: **desert, tropical forest**
5. No cold season: **desert, tropical forest**
6. The locations for the climatographs are

1. Barrow, 2. Kotzebue, 3. Bethel, 4. Cold Bay. Tundra occurs at all locations. The variation in temperatures and precipitation at these four sites shows students a range of climates for Alaska's tundra. Lowland tundra in the southern areas is warmer and can support a greater variety of plants and animals than can tundra above the Arctic Circle.

CHANGES IN LATITUDE WORKSHEET, page 71

1. As the latitude **increases**, the elevation at which tree line occurs **decreases** OR as the latitude **decreases**, the elevation at which tree line occurs **increases**.
2. In other words, alpine tundra occurs at **lower** elevations at high latitudes.
3. Students can use the map to estimate their latitude and then use the graph to estimate the tree line.

CHANGES IN LATITUDE WORKSHEET, page 71



Signs of Cold in the Environment

Section 1
TUNDRA ACTIVITIES

Grade Level: K - 3

State Standards: SL.K.1,SL.1.1 SL. 2.1, SL.3.1, SL.4.1
NGSS: K-PS3-1, 2-LS4-1

Subject: Science

Skills: Predicting, analyzing, observing

Duration: Two sessions, short field observations

Group Size: Whole class

Setting: Indoors and outdoors

Vocabulary: Cold, hypotheses, liquid, solid, temperature, thermometer, warm

Objective:
Students will be able to state how cold temperatures affect the world around them.

Teaching Strategy:
Students investigate signs of cold in their environment.

Materials:
Journal with an observation chart, pencil

Background:
See INSIGHTS *Section 1, Elements that Create Tundra.*

Procedure:
In advance, make an observation chart for each student that directs the student to write her observations. For example, the chart might ask, "How does the cold affect bushes? How does cold affect animals (birds, dogs, cats, moose, fish)? Does snow change when it gets colder?" If possible, staple the chart to a piece of cardboard and attach a pencil with tape and string.

Younger students may draw pictures to record their observations. For older students, each page should include the date, the subject, a drawing of the investigation or the results, and 2 or 3 sentences describing the changes that were observed.

1. Ask students what we mean by **cold** *(absence of heat)*. Discuss how we measure the amount of heat present: *touch, **thermometers**, observation (whether or not water is frozen)*.

2. Ask students how cold affects various things: water, plants, rocks, soil, plastic, animals. Record students' **hypotheses** (assumptions) about what they will find during their investigation.

3. Go outside on **warm** and **cold** days to observe how things are different. Each student records his observations on the charts. Encourage students to listen to the sounds of their feet; to feel the texture of the snow, the brittleness of plant leaves, and the hardness of the ground; and to look for the presence of ice (**solid**) or **liquid** water and for animal activity.

4. Encourage students to look closely at any animals they

see. Are birds' feathers fluffed out when it's warm or cold? Are dogs curled up with their tails over their noses, or are they active? How do students' hands work in the cold? What does the ground feel like?

5. After returning to the classroom, compile a class list of all the signs of cold in the outdoors. Students build the list from their observation chart records. The list could be categorized, for example, into things that they saw, felt, heard, touched, and tasted and behaviors of animals, behavior of humans.

6. Hold a class discussion. Ask students to state their conclusions from the results of their investigation.

Evaluation:
Students describe how cold affects the world around them.

EXTENSION:
Keep a calendar of changes. As spring approaches, keep a class calendar of daily high and low temperatures. Make a contest challenging students to observe the first sign of new plant growth and/or the arrival of various birds. Correlate the date of observation of the first new growth with rises in daily temperatures.

Credit:
This activity was modified by Jean Seaton, primary teacher from Chignik Lagoon.

Curriculum Connections:
(See appendix for full citations)

Books:
Arctic Tundra (Forman)
The Reasons for Seasons (Gibbons)

Scholastic's The Magic School Bus in the Arctic: A Book About Heat (Cole)

Snow and Ice (Steele)

Sunshine Makes the Season (Branley)

This Place Is Cold (Cobb)

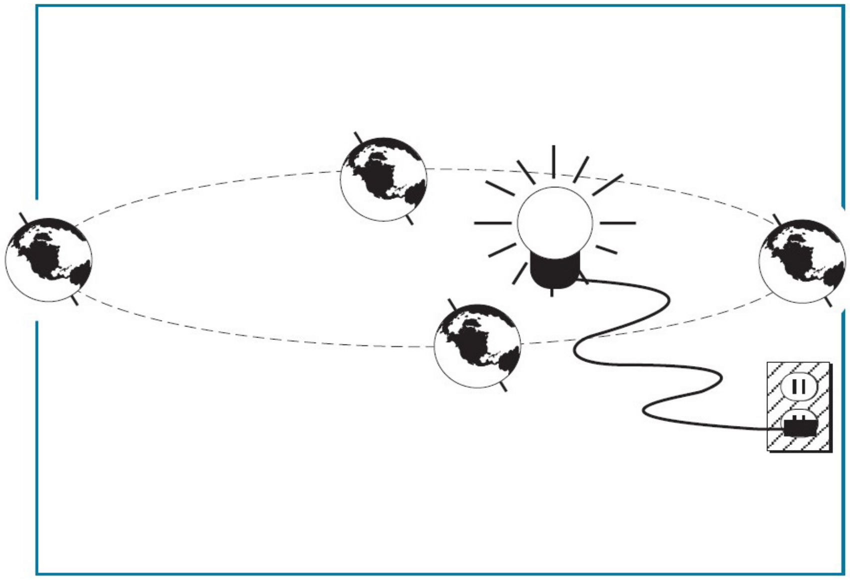
What Makes Day and Night (Branley)

Teacher Resources:
(See appendix)

Is it always cold in the tundra?
Warm – even hot – temperatures
can occur every day at high-elevation tundra
environments.

The Absence of Heat

2 ACTIVITIES, 1 EXTENSION



Section 1
TUNDRA ACTIVITIES

Grade Level: 4 - 12

State Standards: S B-1, S B-5, S B-6, Geo B-1
NGSS: 2-ESS2-3

Subjects: Science, language, arts, geography

Skills: Measuring, inferring, predicting, synthesizing, reading, writing

Duration: 45 - 60 minutes per station

Group Size: Small

Setting: Indoors

Vocabulary: Arctic tundra, atmosphere, lowland tundra, alpine tundra, tundra, solar energy

Objective:
Students will explain how sunlight differs in its heating potential in different parts of the world.

Teaching Strategy:
Students make observations and measurements in two experiments and then make predictions about the distribution of cold environments on the earth.

Prerequisite:
Familiarity with the earth's rotation and revolution, day and night, and seasons (see INSIGHTS *Section 1, Elements that Create Tundra).*

Materials:
An atlas showing world environments, a world almanac, and the materials to set up each of the following experiments:

HEAT ENERGY and the SUN
Materials: An incandescent lamp or direct, bright sunlight; modeling clay; 2 metal lids from frozen juice containers, both painted black; 1 or 2 thermometers; a flashlight; a piece of cardboard; a ball or globe.
Setup: Place 2 lumps of clay, the rest of the materials, and the "Science Card" *(following pages)* at a station.

WIND and AIR TEMPERATURE
Materials: An electric fan; 2 thermometers; 2 identical empty cans; pail of warm water; pan of ice.
Setup: Place the materials and the "Science Card" *(following pages)* at this station.

Background:
See INSIGHTS *Section 1, Elements that Create Tundra.*

Procedure:
IN ADVANCE, set up the 2 stations as described above.

1. IN CLASS, have all groups of students do all investigations or have separate groups do separate investigations and then report their findings to the class.

2. The last questions on each of the "Scientist's Cards" require students to apply their findings to make predictions. Discuss each of these beforehand to ensure that students understand the questions and arrive at reasonable predictions.

3. Ask students to test their predictions. (They may initially think that they need to go to various places on the earth and test the intensity of solar radiation or the rate of heat loss.) Encourage them to question how the amount of solar energy and the rate of heat loss of a particular site would affect its climate and ecosystem.

4. Can students infer that the places on the earth that receive the least solar energy and that lose heat most quickly have the coldest climates? Based on experimental findings, what regions of earth would have the coldest environments? Ask students to use an almanac to determine the climate at various latitudes and elevations on earth.

5. Explain that **tundra** is the name of an environment found in the parts of the earth with the coldest climates. Tundra at high latitudes is called **arctic** (or antarctic) or **lowland tundra**. Tundra at high elevations is called **alpine tundra**.

6. Remind students that it is possible to have alpine tundra at high latitudes. Thus, it is possible to have lowland and alpine tundra next to one another. Ask students to look at an atlas showing photos of lowland and alpine environments throughout the world.

Evaluation:

1. Write a paragraph explaining why environments at high latitudes are cold and why environments at high elevations are cold.

2. Predict how cold temperatures might influence living things in cold environments.

3. Consider the reasons for the cold environments in the two types of tundra areas and predict how these two cold environments differ. Or would they be the same?

EXTENSION:

Create another planet. Students work individually or in teams of 2 to 4 to create a planet similar to Earth using balloons and paper mache or drawing paper. After marking continents and land forms, students label tundra areas and state their reasoning.

Curriculum Connections:

(See appendix for full citations)

Books:

Arctic & Antarctic (Weller)

Biomes of the World - v.1 (Allaby), 7-12

DK Science Encyclopedia (also available on CD)

How the Earth Works (Fardon)

A Naturalist's Guide to the Arctic (Pielou), 9-12

One Small Square: Arctic Tundra (Silver)

Tundra (Kaplan)

Tundra (Sayre)

Tundra (Walsh-Shepherd)

U-X-L Encyclopedia of Biomes - v.3 (Weigel), 7-12

Teacher Resources:

(See appendix)

SCIENCE CARD

Heat Energy and the Sun

Sunlight is made of heat and light energy. When sunlight strikes molecules in the air or on a solid surface, its energy is either reflected or absorbed as heat. Each ray of sunlight contains the same amount of heat and light energy.

Question:
How does the angle at which sunlight strikes an object – the *angle of incidence* – affect the amount of heat and light energy received? This experiment will help you find out whether your ideas are correct.

1. Stand 2 metal can lids, painted black, at different angles, using modeling clay as a base. (*See the diagram.*) Place these an equal distance from an incandescent light bulb (but within a short enough distance that you can feel the heat of the light bulb on your hand) or in direct, bright sunlight.

Wait 15 minutes (go on to the next step while waiting), then feel the temperature difference with your fingers. Which one is warmer? Which one received the most light and heat energy?

2. Shine a penlight against a piece of cardboard. Keep the light close enough that you can see a distinct circle of light. First hold the cardboard straight up and down, and note the size of the circle of light. Then, slowly tilt the cardboard either toward or away from the light.
What happens to the circle of light?

Considering that the amount of light generated by the flashlight has remained the same, how do you think the amount of light energy received per unit area changes as the **tilt** of the cardboard (angle at which the light strikes the surface) increases?

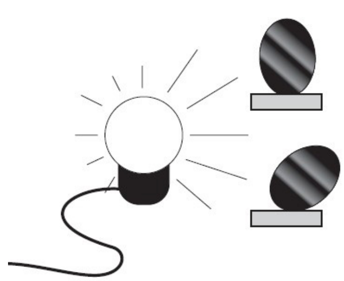
Based on this investigation, can you predict what difference you will find when you measure the temperature of the lids in Step 1?

3. Imagine that the penlight represents the sun. Keeping in mind that the earth tilts on its **axis**, shine the penlight on the globe or ball (representing the earth). Hold the penlight so that the beam of light is *perpendicular to the equator*. Hold the light close enough to the globe that you can see a small, distinct circle of light.

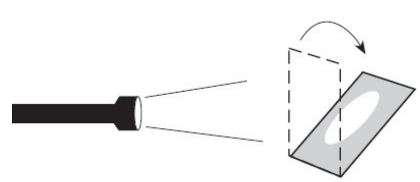
Compare the size of the circle that appears when the light is shown on the equator to the size of the circle when the light is shown at the poles. Be sure to hold the penlight beam *perpendicular to the equator* in both cases.

Based on your observations, what regions of earth receive the most solar energy per unit area (the highest intensity of solar energy)? Which regions receive the lowest?

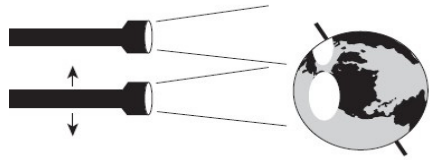
1.



2.



3.



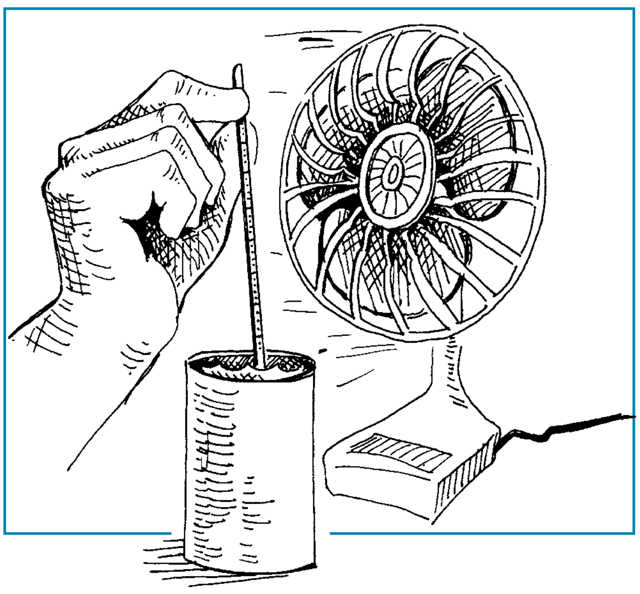
Wind and Air Temperature

Question:
Do you think wind affects the temperature of our environment? This experiment will help you find out whether your ideas are correct.

1. **EXPERIMENT A.** Measure the air temperature about 2 feet (.61 meters) in front of the electric fan, but with the fan turned off. Record this temperature.

2. Turn the fan on high and measure the air temperature again. Wait a few minutes to allow the thermometer to respond to any change. Record any changes.

3. **EXPERIMENT B.** Try another experiment. Fill the 2 cans with warm water and place a thermometer in each one. Record the starting temperature of each. This is important because even if the water temperature in the 2 containers is the same, the 2 thermometers may register slightly differently.



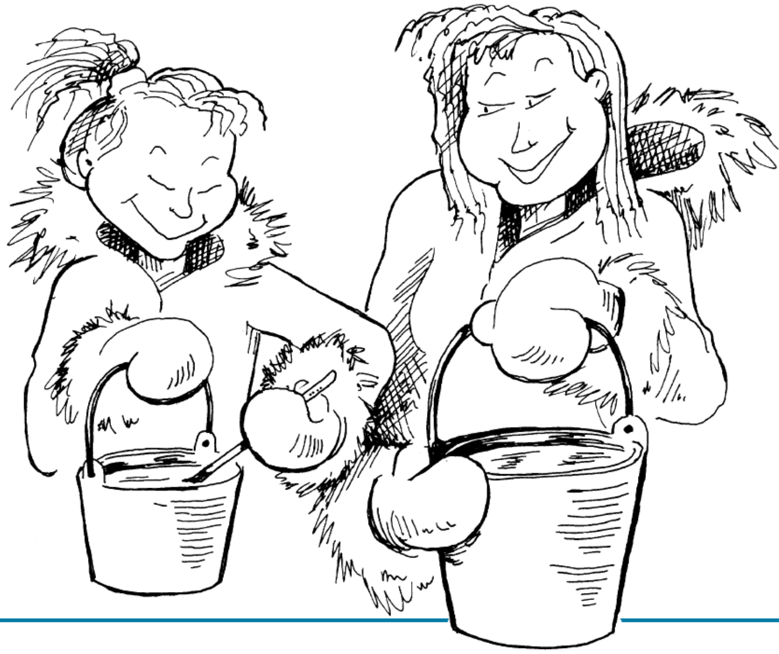
Place one can of water aside, away from the turned-on fan, and the other one in front of the fan. Wait about 15 minutes, then record the temperature of the water in both containers again. Did the temperature in both containers drop the same number of degrees? Which one dropped further? The drop in temperature is a measure of heat loss. After this experiment, how do you think wind affects the temperature of the environment?

4. **EXPERIMENT C.** Try one more experiment. Repeat Step 3, placing a pan of ice between the fan and the can. Wait 15 minutes. Did the temperature in this can drop more, less, or the same amount as in the last experiment? Did it drop more, less, or the same amount as the temperature of the other can? Explain why. What do you predict would occur if you placed a heated surface between the fan and the can?

5. Based on what you observed in these experiments, choose the scenario from each of the following in which a living thing would have the most difficulty keeping warm:

(a) coastal environment adjacent to pack ice with winds blowing toward the shore OR coastal environment near pack ice with winds blowing toward the sea
(b) cold, calm environment OR cold, windy environment

Does the Ocean Freeze?
1 EXTENSION



Section 1
TUNDRA ACTIVITIES

Grade Level: K - 4

State Standards: S B-1, S B-2, S B-5, Geo C-1

Subject: Science

Skills: Predicting, analyzing, observing, measuring

Duration: 30 minutes plus monitoring checks

Group Size: small

Setting: Indoors

Vocabulary: Cold, freezing point, heat, hypotheses, liquid, salinity, solid, temperature

Objective:
Students will be able to state how cold temperatures affect water bodies, including the ocean.

Teaching Strategy:
Students perform an experiment to illustrate the different temperatures of freezing for fresh and salt water.

Materials:
For each group: distilled water, 2 plastic beakers or cups, 2 thermometers, teaspoon, salt, freezer (or outdoors)

Background:
Why doesn't the ocean freeze solidly in the winter even when the air **temperature** drops below the **freezing point** of fresh water, 32°F (0°C)? Movement and **salinity** – saltiness – are two major characteristics of ocean water that help keep it from freezing at that temperature.

Moving water tends to hold **heat** longer than does still water. This can be seen in nature by the early freezing of a still pond compared with the later freezing of rushing rivIn the deep ocean, currents are constantly moving water. Wind also pushes water on the surface of the ocean. As water moves, it retains heat energy. The shallowness of ocean or river shores and beaches restrict the movement of water. "Shelf ice" often forms first along shorelines of beaches and rivers because the still water has less heat energy. The less water moves, the more quickly it freezes.

Salinity lowers the freezing point of ocean water below to 32°F.

Procedure:
1. Students keep a journal of the investigation. Younger students may draw pictures to record their observations. For older students, each page should include the date, the subject, a drawing of the investigation or the results, and two or three sentences describing the changes that were observed.

2. Review procedures for using thermometers and reading temperatures.

3. To illustrate the effects of salt on freezing, fill 2 plastic beakers or cups with distilled water. If one is available, place a thermometer in each container.

4. Ask a student to add salt, one teaspoon at a time to one of the containers of water. Stir the water after each teaspoon is added, making sure that all the salt is dissolved before adding the next teaspoon. Stop adding salt when it ceases to dissolve even when stirred.

5. Mark the first container "salt water sample" to show that it is saturated with salt. Mark the second container "freshwater sample." Put both containers in a freezer or outside, if appropriate. Record students' **hypotheses** (predictions) about what will happen to the two **liquids**.

6. Ask students to check their containers every 15 minutes until each one is at least half-frozen. Record observations on a chart. When the freshwater sample is about half-frozen, note the temperature reading and the amount of time it took to start freezing. Do the same for the salt solution.

7. Compare the time it took for each liquid to freeze **solid** and the temperature at which it froze. What happened? How do we see these differences demonstrated in nature?

Evaluation:

Students describe how cold affects the water around them.

EXTENSION:

Keep a freeze-up calendar. Keep a class calendar of daily high and low temperatures. Make a contest challenging students to observe the first sign of freezing (or thawing) in your local water bodies. Correlate the date of observation with changes in daily temperatures.

Credit:

This activity was modified by Jean Seaton, primary teacher from Chignik Lagoon.

Curriculum Connections:

(See appendix for full citations)

Books:

Scholastic's The Magic School Bus in the Arctic: A Book About Heat (Cole)

Snow and Ice (Steele)

Snow, Ice and Cold (Stonehouse)

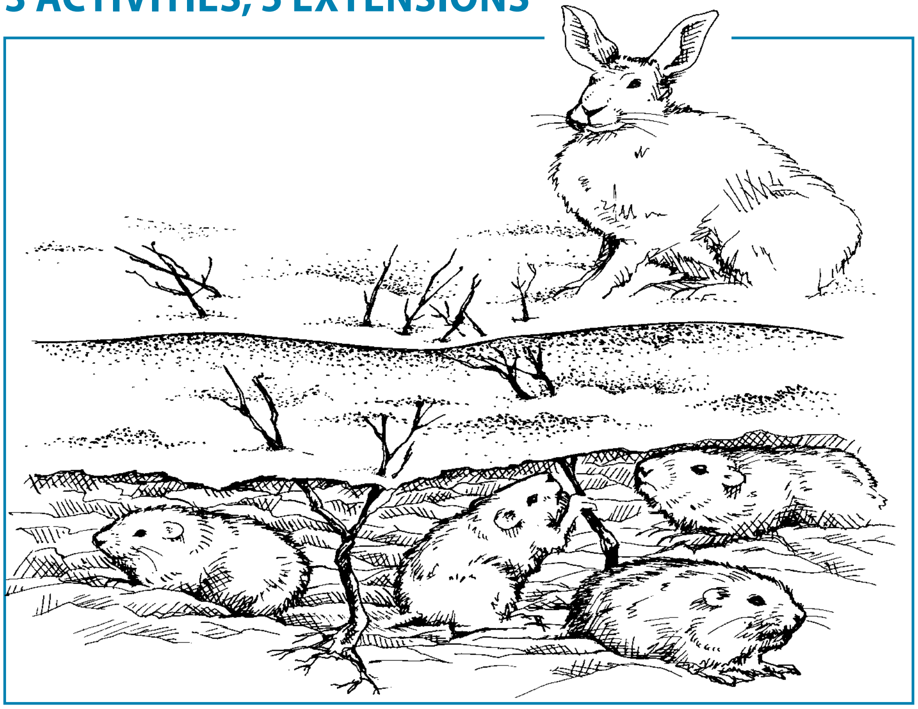
Teacher Resources:

(See appendix)

Moving water tends to hold heat longer. Large, deep lakes freeze later than do small, shallow ponds. The salty ocean freezes later than do freshwater lakes.

Snow Blanket

3 ACTIVITIES, 5 EXTENSIONS



Section 1
TUNDRA ACTIVITIES

Grade Level: K - 9

NGSS: K-PS3-1, K-LS1-1, MS-PS3-3.

Subjects: Science

Skills: Analyzing, estimating, predicting

Duration: 2 days: 45 minutes each

Group Size: 2 - 3

Setting: Indoors & outdoors

Vocabulary: Air, conductor, heat energy, insulator, snow crystals

Objective:

Students will describe the insulating function of snow in an ecosystem.

Teaching Strategy:

Students perform a series of simple experiments to show that snow creates insulation that can keep animals warm.

Materials:

For each group: 2 clear jars, marking pen or tape, box of corn flakes, 2 film canisters or margarine tubs (at least 1 container per group should have a lid), powdered gelatin, 2 thermometers, snow shovel or trowel.
OPTIONAL: hand lenses, embroidery hoops, down-filled clothing or sleeping bag, clear plastic or dark fabric.

Background:

See INSIGHTS *Section 1, Elements that Create Tundra.*

Procedure:

DAY ONE:
EXPERIMENT A
Optional: IN ADVANCE, prepare enough hand lenses and snow catchers so that each team of 2 to 3 students has one of each. Tie hand lenses to a yarn necklace. Make snow catchers by stretching clear plastic wrap or dark fabric over a small embroidery hoop.

1. Ask students to pretend they have a visitor from a hot, sunny country who has never seen snow. Ask them to describe snow to the visitor. Make at least 3 categories on the board as you record their ideas. For example, students may describe snow's appearance, the games they play in it, and the effects it has on our lives or animals' lives.

2. Take the class outside to look at falling snowflakes. Tell students that they will measure snow. A volunteer should carry a clear jar or pitcher to collect fresh snow. Explain that each snowflake snow crystal has six sides, but no two snowflakes are identical.

3. Working in teams of two or three, students may "catch" snowflakes on their jacket sleeves (darker colors show off the snow better) or other snow catchers and examine each flake's design. If possible, students should use hand lenses.

4. Collect a snow sample in the jar and mark the level of

snow on its side by using a marking pen or tape.

5. After returning to the classroom, ask students to estimate how many minutes it will take for the snow to melt. Record all of the students' time estimates on the board.

VARIATION:

Collect 2 samples and place one near the heater and one near the window.

6. Ask one student to be the official "snow checker." She will announce when the snow has melted. After the snow has melted, check the class's estimates to discover who was closest to the right time.

7. Mark the level of water in the jar with a marker or tape. Ask students what they think was taking up the space between the snow mark and the water mark. *Snow crystals are solid water molecules that are separated by air until they melt. Liquid water molecules have little or no air between them.*

EXPERIMENT B

1. Prepare for the next demonstration by asking students to brainstorm another way to do the first experiment using something besides snow flakes. Suggest food items containing air. For example, anything that is whipped or frothy such as whipped cream; or, anything dry that can be crushed or squished to lesser volume such as crackers or dry cereal.

2. Fill a jar or pitcher with corn flakes. Mark the fill level on the jar. Ask a volunteer to crush the flakes to simulate melting snow. Mark the new level of flakes in the jar and discuss how much space in the jar (and in the cereal box) was taken by air.

3. Help students generalize and apply what they've observed in the preceding demonstrations. Some animals such as mice, lemmings, and insects live beneath the snow in the winter. How can the air in the snow help these animals? Explain that *they can breathe the air, and the trapped air insulates them from the cold.*

DAY TWO

EXPERIMENT C

1. Choose a shaded area and perform this experiment early in the day to avoid the warmth of direct sun.

2. Explain to the students that they will be working with a powder called gelatin that dissolves in hot water and thickens when cooled.

3. Fill a measuring cup with hot water. Empty one package of gelatin into water and stir thoroughly. Fill all film canisters or margarine tubs half full with the gelatin solution.

4. Divide students into groups of two or three. Each group chooses a shaded site to dig a snow pit one foot deep. Give each group two film canisters, one lid, and two thermometers. Students place the canister without the lid on the surface of the snow and bury the other canister with the lid one foot deep in the snow. Place one thermometer next to each of the canisters.

5. After five minutes, check the surface canisters for signs of jelling. When they begin to jell, students dig up the buried container and compare the progress of the two. *(The container above the snow should have jelled first.)*

6. Check the thermometers. Students should find that the top layer of snow is cooler than the deeper, more thickly insulated levels.

7. Discuss with the students that snow acts as an insulator, just like a blanket or a jacket. Some animals depend on snow to keep them from getting too cold in the winter. For example, lemmings in the Arctic spend their entire winter under the snow, not hibernating, but actively scurrying around eating, avoiding predators, and having babies.

8. Discuss the basic similarity between snow and many common insulation materials such as down fill and Styrofoam. *(They all trap air!)*

Evaluation:

1. Finish the sentence "Snow is like a blanket because. . ."

2. Could people live under the snow? Why or why not?

3. Windblown ridges in the north are often barren of plant life. Apply what you know about snow to speculate why

plants don't grow on these ridges.

EXTENSIONS:

A. **How much insulating air is in compacted snow?** Fill two clear containers, one with fresh snow and one with snow that has been crammed into the container by students to represent compacted snow. Fill to the same level. Allow the snow to melt and compare the amount of air in the fresh snow to the lesser amount in the compacted snow.

B. **Compare the insulating value of tracked and untracked snow.** Repeat the DAY TWO part of this activity in compacted snow. Choose a site that has been trodden by people or vehicles. Be sure to read thermometers carefully.

C. **Make "Baked Alaska!"** Follow cookbook directions to prepare this delicious dessert. Baked Alaska is a layer of cake topped by a thick layer of ice cream, covered by an inch of meringue (whipped egg whites) and then baked for three to five minutes. The ice cream does not melt because the meringue is a poor heat conductor. Like snow, meringue is full of air bubbles that don't carry heat well. Meringue insulates the ice cream from the oven's heat.

D. **Design a make-believe "animal" that could thrive under or in the snow** during the winter *(see also "Design Your Tundra Animal" in Section 3).*

E. **Build "Blubber Mitts" that illustrate the insulating properties of fat.** Make your own insulated mitts *(see "Blubber Mitts" in Section 3).*

Credit:

EXPERIMENT C of this activity was adapted and reproduced from Hands-On-Nature, 1986, with permission of the publisher: Vermont Institute of Natural Science, 27023 Church Hill Road, Woodstock, VT 05091.

Curriculum Connections:

(See appendix for full citations)

Books:

One Small Square: Arctic Tundra (Silver)

Scholastic's The Magic School Bus in the Arctic: A Book About Heat (Cole) K-3

The Secret Language of Snow (Williams)

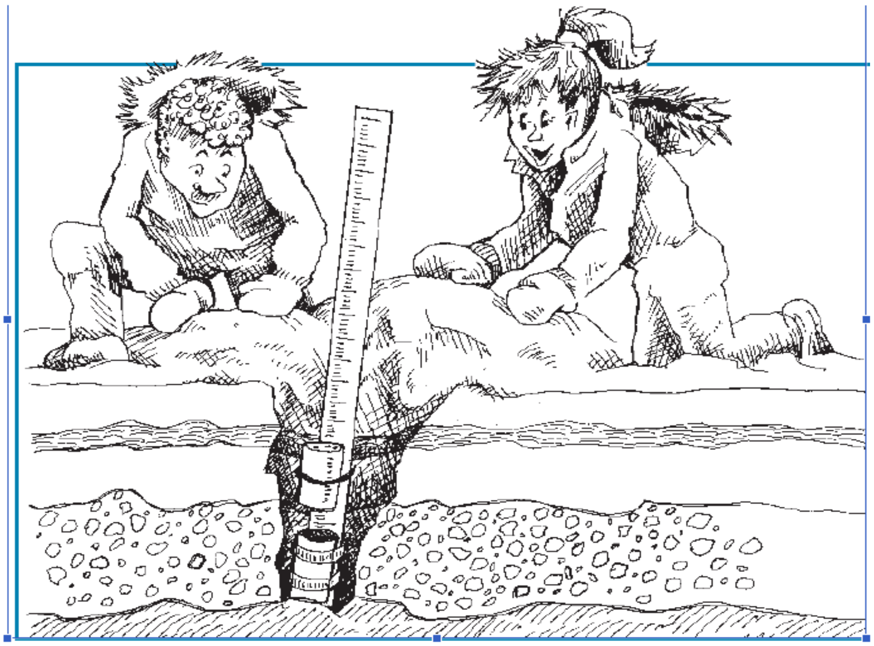
Tundra (Sayre)

Teacher Resources:

(See appendix)

Snow is a good insulator because air is trapped between snow crystals. Air is a poor conductor of heat; therefore, objects surrounded by snow-trapped air stay warm.

Snow Compaction
2 EXTENSIONS



Section 1
TUNDRA ACTIVITIES

State Standards: 4.MD.5,5.MD.3
NGSS: MS-ESS3-3,HS-ESS2-5
Subjects: Science, social studies, math
Skills: Measuring, comparing, inferring, graphing
Duration: 2 sessions: 30 minutes to construct dipstick; 45 - 75 minutes for activity
Group Size: Small
Setting: Outdoors or indoors
Vocabulary: Compacted, compaction, constructive snow metamorphism, density, depth hoar, insulating ability, insulation, sublimation, subnivean, temperature gradient, uncompacted

Objective:
1. Students will measure and compare temperatures beneath compacted and uncompacted layers of snow.

2. Students will determine the effects of compaction on the value of snow as insulation.

Teaching Strategy:
Students measure the density of compacted and uncompacted snow, predict the temperature under the 2 kinds of snow, and measure it to test their predictions.

Materials:
Each group – for constructing a thermometer dip stick *(see following diagram)*: 1 cardboard juice can, 1 tin can (12 oz), 1 meter stick, 1 thermometer, 1 rubber band, 1 roll duct, strapping, or electrical tape; for collecting snow: measuring cup or container of known volume; graph chart or large grid paper to record and graph results.

Background:
See ***INSIGHTS Section 1, Elements: "Precipitation."***

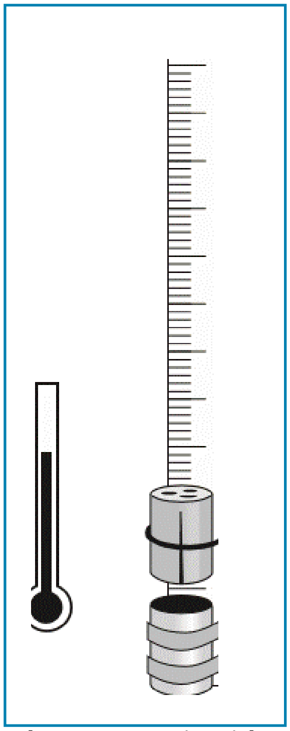
Procedure:
IN ADVANCE, locate sites with compacted and uncompacted snow so that you can take students directly to the sites when you go outdoors.

IN ADVANCE *(for younger students)*, construct a dip stick for measuring temperatures underneath snow:
(a) Remove one end from each of the cans. Punch 3-4 holes in the other end of each can.
(b) Tape the metal can to the base ("zero" end) of the meter stick with 2 bands of tape *(as illustrated)*. The bottom of the can should be even with the bottom of the stick.
(c) Slit the side of the cardboard juice can so it can easily slide inside the metal can. Attach the juice can to the meter stick with a rubber band. It should be tight, but still able to move along the meter stick. This cardboard can forms a moveable lid for the metal can.
(d) Place the thermometer in the compartment formed by the 2 cans.
Leave the dip stick outside for 30 minutes prior to using it.

1. IN CLASS, discuss the activity with students. Ask them to define **density**. Put definitions on the board. Ask for their predictions. Reinforce the concept that snow is actually made of water.

2. Ask students to collect equal volumes (1 cup or so) of **compacted** and **uncompacted** snow. Bring the snow inside and let it melt. Measure the water and compare volumes. Ask students to hypothesize why the volumes were equal as snow, but different as water. What else was in each cup? *(Air)*

3. Explain to students that compacted snow actually contains more water per inch of depth than uncompacted snow. Ask which would provide better **insulation**. Ask the class to vote and record the results.



Thermometer Dip Stick

4. OUTDOORS, demonstrate the technique for measuring the **temperature** under a layer of snow:
(a) Poke the end of the dipstick without the can into the snow and rotate it to create a hole large enough for the can.
(b) Remove the stick and turn it over so that you can place the can with the thermometer in the snow. Refill the hole with nearby snow.
(c) Record the depth of the snow from the meter stick.
(d) Wait 15 minutes, then pull the stick out of the snow, quickly open the thermometer case, and read the thermometer.

5. Students also measure and record the outside air temperature.

Many small mammals are active all winter beneath the snowpack. They live in the subnivean layer between the ground and the snow.

6. Then students measure the temperature under *uncompacted* snow. Take measurements from more than one location: for example, under a snow drift, under snow in a sheltered spot, and in a wind-blown spot. Record the site description, depth of the snow, and the temperature measurement under the snow.

7. Next, have students measure the temperature of the air under *compacted* snow: for example, under the tracks of a snowmachine, four-wheeler, dogsled, ski, or walking trail. Take measurements from several different sites. At each site, record a description of the site, the depth of the snow, and the temperature.

8. IN CLASS, make a graph on the board showing temperature at various snow depths. Each group graphs its results. Record measurements from uncompacted snow in one color, and measurements from compacted snow in another. Discuss the results. Which sites were better insulated (had the warmest temperatures)?

9. In class discussion, consider the consequences of driving vehicles over the tundra. How will snow compaction affect plants and animals that live under the snow during winter? *(It would reduce winter survival of these living things. The insulating value of a layer of snow may be reduced 100 percent by compaction.)* What are the effects of driving vehicles across the tundra in winter? How might harmful effects be minimized?

Evaluation:

1. Contrast the temperature of the area beneath compacted snow with the temperature beneath uncompacted snow. Explain any differences.

2. Explain how compacted snow affects shrews, voles, and other animals that live beneath the snow in the winter?

EXTENSIONS:

A. **Graph results and relate to tundra life.** Students graph temperature differences under snow at compacted and uncompacted sites and describe the effects of compaction on plants and animals.

B. **Apply knowledge to tundra travel**. Students answer the following question in writing:

"You are out in the tundra and you need to travel 15 miles. How do you plan to get from point A to point B, and why have you chosen this method?" *Remember you do not own an airplane, and you have no money to charter one. You are aware of the impacts of compacted snow and you wish to do as little damage as possible.*

Students critique each other's responses.

Curriculum Connections:

(See appendix for full citations)

Books:

One Small Square: Arctic Tundra (Silver)

The Secret Language of Snow (Williams)

Snow and Ice (Steele)

Teacher Resources:

(See appendix)

Words for Snow

laska's Natives have a vocabulary that describes snow in detail.

Below are a few examples.

Inupiaq (North Slope)

apun	snow
aniu	packed snow
apigaa	it is covered with snow
auksallak	wet, heavy, melting snow
natigviguq	there is blowing snow at ground level
pukak	crystallized snow
qannik	snowflake
qimuagruk	snowdrift

Athabascan (Ahtna)

nadaexi	falling snow
tsiitl'	snow on ground
tsiitl' kaggagi	hard-packed snow
hwdlii	crusted snow
sesi	packed compacted snow
sesdon	packed snow on trail
ggaet	trampled snow

Yup'ik (Central)

nutaryuk	fresh snow
muruaneq	soft, deep snow
aqigtaq	soft, melting snow on the ground
ganikcaq	snow on the ground

Permafrost blocks water drainage and keeps the above soil layer saturated and prone to freezing and thawing.

Tundra Topography
3 EXTENSIONS

Section 2
TUNDRA ACTIVITIES

Grade Level: 4 - 12
State Standards: SL.4.4, SL.5.4
NGSS: 4-ESS2-1,4-ESS2-2.,4-ESS3-2. MS-ESS2-2,MS-ESS3-3,HS-ESS2-5 HS-ESS3-4.
Subjects: Science, geography, language arts, art
Skills: Vocabulary building, team-work, spatial relations
Duration: Two 45 minute classes
Group Size: Partners or small groups
Setting: Indoors
Vocabulary: Active layer, frost boils, high-center polygon, ice wedges, low-center polygon, permafrost, pingo, slumping, solifluction/ gelifluction, talik, thermokarst, wetlands

Objective:
Students will describe 5 varieties of tundra topography.

Teaching Strategy:
Students read about and construct models of characteristic lowland tundra topography.

Complementary Activities:
"Permafrost" in this section; *"Vehicles on the Tundra"* and *"Puzzler: Tundra and Permafrost – Icy Balance,"* both in *Section 5, Human Impacts.*

Materials:
Copies of "Permafrost Features" from INSIGHTS *Section 2* for each student, blocks of modeling clay or batches of baker's clay or play dough *(recipes at end of activity)* for each group, cardboard box (or similar container) about 4 x 6 inches (10 x 15 centimeters) to hold the modeled tundra topography.

OPTIONAL: container with one or more see-through sides.

Background:
See *INSIGHTS Section 2, Topography and Soil.*

Procedure:
1. Students read the descriptions of tundra topography in INSIGHTS *Section 2*.

2. Divide the class into groups of 2 to 4 students with each group focusing on one of the following features: **frost boils**, **high-center polygons**, **ice wedges**, **low-center polygons**, **pingos**, **slumping**, **solifluction/ gelifluction**, **taliks**, **thermokarsts**.

3. Give each group a block of modeling clay, baker's clay, or play dough to build a model showing a topographic feature of permafrost soil. Models can be finished in small containers. Some topographic features such as talik and ice wedges may be more suited for a see-through type of container.

For example, the model may demonstrate the thermokarst depressions created by vehicle traffic over the tundra. Details could include small "lakes" draining into the road or model cars "driving" on the roads. Using the correct terminology, students label their models.

4. Each group should freeze its model if appropriate and/or add water to represent the flow of surface moisture. Some models will be more realistic if actually constructed with water added in repeated freeze-and-thaw steps.

5. Each group describes its model and topographic features to the class. When describing the model to the class, students use accurate terminology and concepts.

Evaluation:

Students describe and illustrate five types of tundra topography.

EXTENSIONS:

A. **Talk with engineers or geologists.** Students research the topographic features with engineers and geologists in the area. Contact engineers who specialize in tundra soils. Invite them to present information to the class.

B. **Create a mural.** Students create a mural showing the parts of tundra (including soil). Students attach labels and descriptions to the mural.

C. **Apply knowledge to road damage.** Using the information gathered from this lesson, students answer the following question: "Why does a road break, buckle, and form potholes in the spring?" Students will design and perform an experiment to demonstrate this phenomenon. They may choose to conduct another experiment showing other effects of permafrost on soil.

Curriculum Connections:

(See appendix for full citations)

Books:

A is for Arctic (Lynch)

The Arctic Land (Kalman)

Biomes of the World - v.1 (Allaby) 7-12

Land Above the Trees: A Guide to American Alpine Tundra (Zwinger) 9-12

A Naturalist's Guide to the Arctic (Pielou) 9-12

Tundra (Kaplan)

Tundra (Sayre)

Tundra (Walsh-Shepherd)

U-X-L Encyclopedia of Biomes - v.3 (Weigel) 7-12

Website:

How ice wedges and permafrost features are created (link to "Habitat") <arctic.fws.gov>
(Arctic National Wildlife Refuge)

Teacher Resources:

(See appendix)

Baker's Clay

4 parts flour
1 part salt
1.5 parts water

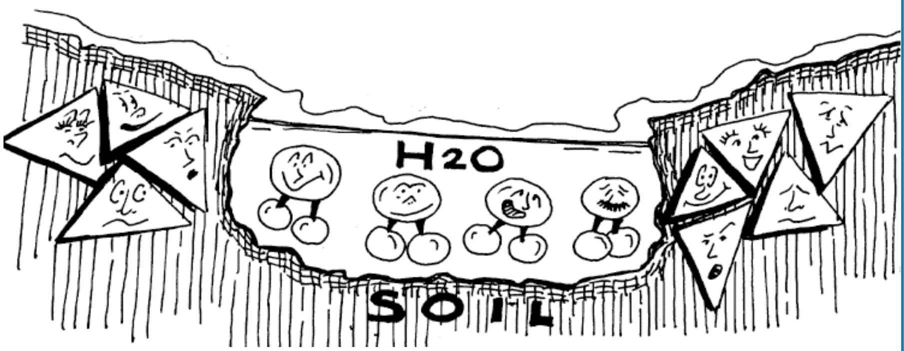
Adjust proportions to make clay capable of being formed and modeled. Mix with hands and knead 6 minutes. Baker's clay may be air-dried or baked in moderate oven one hour or more until hard. Additions may be glued on with diluted white glue.

Play Dough

1 cup salt
1.5 cups flour
0.5 cup water
2 tablespoons oil
food coloring (optional)

Mix oil into water. Mix all ingredients together with hands. Knead on table. Store in refrigerator.

Edible Permafrost



Section 2
TUNDRA ACTIVITIES

Grade Level: K - 6

NGSS: 2-ESS2-2, 2-ESS2-3,4-ESS2-1

Subjects: Science

Skills: Analyzing, predicting, following directions, observing, synthesizing, applying

Duration: two 15-minute sessions

Group Size: Whole class

Setting: Indoors

Vocabulary: Active layer, permafrost, snow, soil

Objective:

Students will experience the impermeability of permafrost and learn why the tundra is wet and has so many lakes even though, by definition, it is a desert.

Complementary Activities:

"Tundra Topography" and *"Heaving and Thawing in the Classroom,"* both in this section; *"Vehicles on the Tundra"* in *Section 5, Human Impacts.*

Materials:

For each student: 1 clear plastic cup or container, chocolate ice cream, vanilla ice cream, clear gelatin. Pictures of tundra with lakes (available in *"Permafrost Features," Section 2 INSIGHTS*).

Background:

See *INSIGHTS Section 2, Topography and Soil: "Permafrost Features."*

Procedure:

1. Explain to the students that they will be making a model of the tundra in a cup – and that afterward they can eat their project.

2. Talk about **permafrost**, what it is *(permanently frozen soil),* and the fact that it doesn't melt – even in the summer. Remind students that precipitation on the tundra is so limited, the land could be a desert.

3. Following directions on the package, students prepare the gelatin and pour several inches of "permafrost" into each cup. Chill to set overnight, *or* for one hour (or less) if put in the freezer – *read a tundra story or go on to another lesson while the gelatin is firming.*

4. Students spoon into their cup a layer of **"soil"** (chocolate ice cream) without disturbing the gelatin layer. This is the upper layer of soil that thaws each summer and is called the **active layer**.

5. On top of that, students add a layer of **"snow"** (vanilla ice cream).

6. Ask the students to predict what will happen, if the layers all mix. Let the cups sit (and start melting) while you discuss tundra or continue reading a tundra story.

7. Draw students' attention to the cups, the mixing of "snow" and "soil" sitting atop the "permafrost." Show them the picture of tundra with lakes.

8. Ask them why the tundra is so wet. *Water from the melting snow and rainwater cannot pass through permafrost's icy block, so water stays near the surface and forms marshes and lakes – just like in their cups.*

9. Eat up!

Credits:

Adapted by Jeanne L. Williams, Kingikmiut School, Wales, Alaska, from "One Small Square: Arctic Tundra" by Daniel Silver, W. H. Freeman and Co., 1994.

Curriculum Connections:

(See appendix for full citations)

Books:

Arctic Tundra (Forman)
Arctic Land (Kaplan)
One Small Square: Arctic Tundra (Silver)

Website:

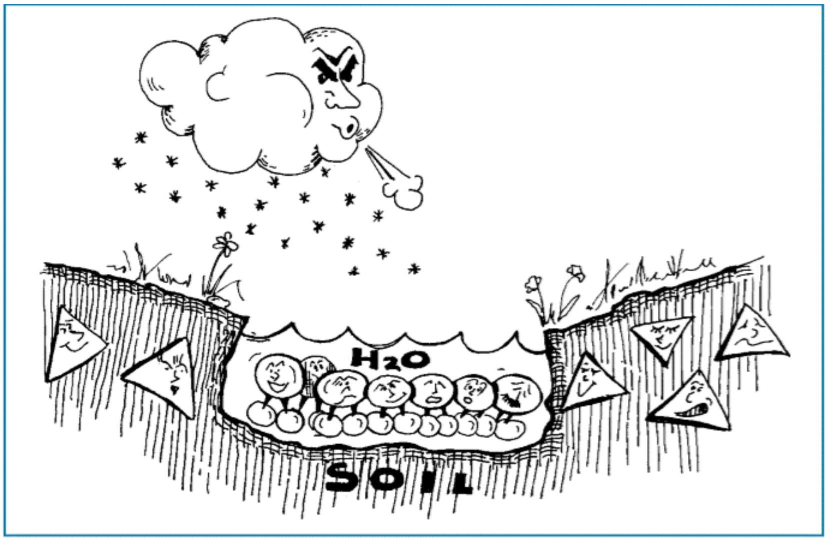
U.S. Fish and Wildlife Service's Arctic National Wildlife Refuge website <arctic.fws.gov> shows how ice wedges and permafrost features are created (under "Habitat").

Teacher Resources:

(See appendix)

Heaving and Thawing in the Classroom

2 EXTENSIONS



Section 2
TUNDRA ACTIVITIES

Grade Level: K - 4

NGSS: 2-ESS2-3, 4-ESS2-1.

Subject: Science

Skills: Observing, predicting

Duration: 2 class periods

Group Size: Whole class or small groups

Setting: Indoors

Vocabulary: Permafrost, prediction

Objective:

1. In a simulation and by observation, students will see the effects of freezing on water.

2. Using a model, students will observe the effects of permafrost on soil.

Teaching Strategy:

Students simulate permafrost by freezing soil in a pan and by pretending they are freezing water molecules.

Complementary Activities:

"Permafrost" in this section; *"Vehicles on the Tundra"* in *Section 5, Human Impacts.*

Materials:

2 shallow (2 inches [5 centimeters] or higher) baking pans, plastic container with a tight lid, freezer, soil, water, fork, tablespoon.
OPTIONAL: masking tape.

Background:

See *INSIGHTS Section 2, Topography and Soil.*

Procedure:

DAY ONE

1. To demonstrate the effects of freezing water, completely fill a plastic container with water and seal it with a lid. Ask students what they think will happen when the container has been in the freezer for a while. Put it in the freezer, or outside if temperatures are below 32°F, until the next day.

2. Fill one flat pan with at least 2 inches (5 centimeters) of moist soil. Ask students what they think will happen when the container has been in the freezer for a while. Put it in the freezer until the next day to find out. Fill another cake pan half full of moist soil, but do not freeze it. (You may want to divide the class into small groups and provide a set of materials for each group.)

3. Discuss **permafrost**. If students do not know what it is, explain that it is a word used to describe soil that is frozen year-round. Is there permafrost on the playground? Take the opportunity to find out. In the fall, you can find out by driving a metal rod into the ground as far as possible, or by digging a hole until you hit ice. If you are using this lesson in the spring, the ground may be frozen even in areas that do not have permafrost.

4. Discuss with students when they think the ice in the ground melts. Check the depth of the ice weekly until school is out and encourage students to continue checking throughout the summer to find out whether permafrost occurs in your area.

DAY TWO

1. After students understand the definition of permafrost, ask them how permafrost soil differs from unfrozen soil. Encourage them to make some **predictions**, or hypotheses, by asking them questions: Would it be warmer or colder? Harder or softer? Would it soak up more or less water? Would it take up more or less space?

2. Retrieve the pan of soil from the freezer and ask students to test their predictions by comparing the soil in the 2 pans. Ask a student to stick a fork in the soil to find out which is hard or soft. Have students pour a tablespoon of water on each of the pans. What happens to the water? Does one pan soak up the water?

3. Remove the sealed plastic container of water from the freezer. Ask students what made the container's sides "push out" or break. *Explain that water expands (gets larger) when it freezes. There was not enough space in the container to hold the expanded, frozen water, and it pushed out the container.*

4. Students pretend to be water and act out the process of freezing. Ask all the students to stand close together in a circle. Draw a circle around them or mark one with tape on the floor, so they can see that they are inside it.

5. Explain that each one represents a water molecule. When the water is liquid, the molecules can "stand" side by side; but when water freezes, it forms ice crystals which take up more space. To form ice crystals, each water molecule must spread its arms straight out to the sides and touch the fingertips only of another water molecule. What happens to the water?

Evaluation:

1. Students define permafrost and give one example of its effect on soil.

2. Students describe how water changes when it freezes and what effect this might have on soil.

EXTENSIONS:

A. **Make models of permafrost features.** Use the photos of *"Permafrost Features"* in *INSIGHTS Section 2* to show the topographic features of permafrost soils. Students make replicas of the various features with modeling clay or play dough.

B. **Apply knowledge to potholes**. Using the information gathered from this lesson, students answer the following question: "Why does a road break, buckle, and form potholes in the spring?" Students will design and perform an experiment to demonstrate this phenomena. They may choose to conduct another experiment showing other effects of permafrost on soil or buildings.

Curriculum Connections:

(See appendix for full citations)

Books:

The Arctic Land (Kalman)

Arctic Tundra (Forman)

One Small Square: Arctic Tundra (Silver)

Tundra (Kaplan)

Tundra (Walsh-Shepherd)

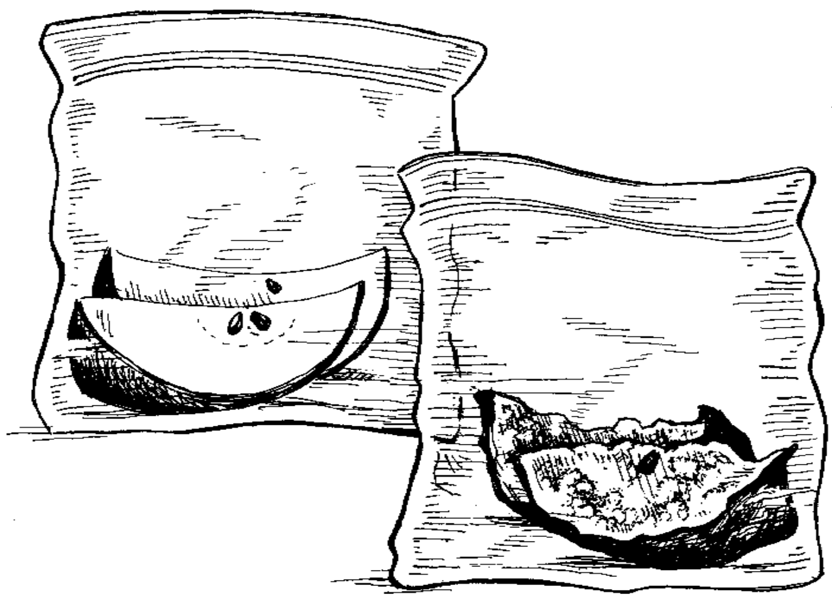
Website:

How ice wedges and permafrost features are created (link to "Habitat") <arctic.fws.gov> (Arctic National Wildlife Refuge)

Teacher Resources:

(See appendix)

Decomposition and Cold



Section 2
TUNDRA ACTIVITIES

Grade Level: K - 3

NGSS: 2-LS4-1

Subject: Science

Skills: Predicting, analyzing, observing, measuring

Duration: Short sessions over two weeks

Group Size: Whole class

Setting: Indoors

Vocabulary: Cold, decomposition, detritivores, hypotheses, peat bogs, temperature, tundra, warm

Objective:
Students will be able to state how temperatures affect decomposition.

Teaching Strategy:
Students perform an experiment to test decomposition under different temperatures.

Complementary Activities:
"Permafrost" in this section; *"Growth and Cold"* in *Section 3, Life Forms and their Tundra Adaptations.*

Materials:
Fresh apple slices or moist bread, 4 or more sealable plastic containers or sealable plastic bags, thermometers.

Background:
See *INSIGHTS Section 2, Topography and Soil: "Cold and Decomposition."*

Procedure:
1. Review procedures for using thermometers and reading temperatures.

2. Students keep a log of the investigation with younger students drawing pictures to record their observations. For older students, each page should include the date, the subject, a drawing of the investigation or the results, and 2 to 3 sentences describing the changes observed.

3. Ask students what would happen to a section of apple placed inside a sealed plastic container. *Suggest that nothing could get into a sealed container, so probably nothing would happen – right?*

4. Record students' **hypotheses** (*assumptions*) about what they will find during their investigation.

5. Put a slice of moist apple in each of 4 or more sealed containers. Put each of the containers in a different environment: (a) in a **cold** place, (b) in a cool place, (c) in a **warm** place, and (d) in a hot place. Measure the **temperature** of each place and record.

6. Ask students to examine the containers once each week and record the changes. Students try to figure out what happened. How did cold affect the process of decay? *(Cold temperatures keep microorganisms such as bacteria from multiplying quickly. Such microorganisms –* ***detritivores*** *– decompose living tissues.)*

7. Hold a class discussion at the end of the investigation. Ask students to state their conclusion from the results of their investigation. What happens in the cold tundra environment? *(Decomposition is slowed. This has three major consequences: (1) formation of new soil is slowed; (2) plant growth is limited by slow recycling of nutrients from decay; and (3) partially decayed plant material may build up into* ***peat bogs****.)*

Evaluation:

Students describe how cold affects decomposition.

Curriculum Connections:

(See appendix for full citations)

Books:

One Small Square: Arctic Tundra (Silver)

This Place Is Cold (Cobb)

Teacher Resources:

(See appendix)

Cold retards the rate of decomposition in the tundra. The slow rate of decomposition (recycling of nutrients) in turn profoundly influences the entire tundra environment.

Rotting in the Cold Tundra

Grade Level: 3 - 12

NGSS: 5-LS2-1, MS-LS2-3, HS-LS2-4. HS-LS4-5

Subject: Science

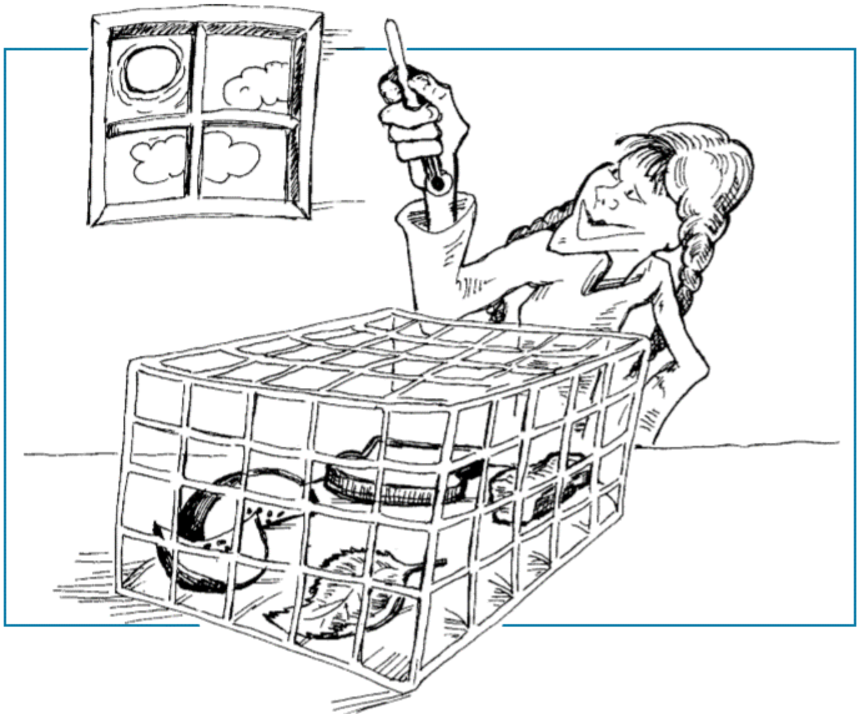
Skills: Observing, comparing, inferring, predicting

Duration: Several short lessons over 2 weeks

Group Size: Whole class or small group

Setting: Indoors

Vocabulary: Decomposition, detritivores, limiting factor, peat bogs, soil formation



Objective:

1. Students will describe how temperature affects decomposition in tundra ecosystems.

Teaching Strategy:

In an experiment, students expose organic material to various temperatures and examine the effects.

Complementary Activities:

"Permafrost" and *"Rotting and Freezing"* in this section; *"Rooting in the Bright Tundra"* and *"Rooting in the Cold Tundra"* in *Section 3, Adaptations***.**

Materials:

For each station or group: 3 wire mesh containers such as sieves or small cages, 3 small pieces of meat, 3 small pieces of fruit, 3 small pieces of bread, 3 dead leaves; thermometers; cardboard; masking tape.

Background:

See *INSIGHTS Section 2, Topography and Soil: "Cold and Decomposition."*

Procedure:

1. Students will carefully observe their experiments and record their observations in journals.

2. Discuss the significance of **decomposition** in **soil formation**, plant growth, and a healthy food web. Ask students to predict what happens in an **ecosystem** that has a very slow rate of decomposition. Students record their predictions in their journals.

3. Cut a piece of cardboard slightly larger than the cage or sieve opening (one for each wire mesh container). Place one of each type of food on each piece of cardboard. Turn the cage or sieve upside down over the food and seal the cardboard to the cage opening with masking tape to keep out insects.

4. Choose 3 sites: (1) one with a freezing temperature, (2) one with a cool temperature, (3) one with room temperature. Place a wire mesh container in each of the three sites and leave for two weeks.

5. Every day, record the air temperature beside each container. Record the daily changes in appearance, color,

texture, and smell of the food in the journal. In which container did decomposition occur the fastest? The slowest?

6. At the end of the 2 weeks, students discuss their experiment in class. Ask students to summarize their observations and compare their experiment results to the tundra environment. Discussion questions include:
• Why is freezing important to decomposition?
• What are the rates of decomposition in tundra environments?
• Do these processes occur faster or slower than in warmer environments?
• How might the rate of decomposition affect plant growth and the number of animals living in a particular environment?

Evaluation:
Students write a summary of the ways temperature affects the recycling of nutrients and explain why tundra soil is less rich than soil in other environments.

Credit:
Adapted from *Yukon Environmental Handbook, Part One: Small Winter Lif*e, Yukon Department of Education. Whitehorse, Yukon, Canada, 1982.

Curriculum Connections:
(See appendix for full citations)

Books:
A Naturalist's Guide to the Arctic (Pielou) 9-12

One Small Square: Arctic Tundra (Silver)

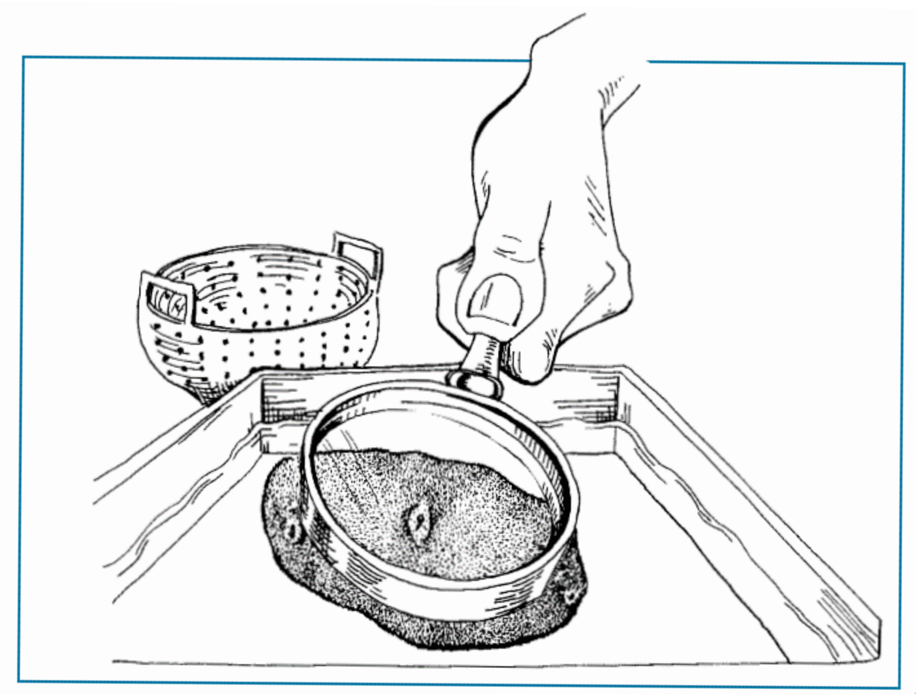
Tundra (Sayre)

Websites:
Alaska Science Forum
<www.gi.alaska.edu/ScienceForum>

Alaska Statewide Databases <sled.alaska.edu>

Teacher Resources:
(See appendix)

Rotting and Freezing



Section 2
TUNDRA ACTIVITIES

Grade Level: 3 - 12

NGSS: 5-LS2-1, MS-LS2-3, HS-LS2-4.

Subject: Science

Skills: Observing, comparing, inferring, predicting

Duration: Several short lessons over 2 weeks

Group Size: Whole class or small group

Setting: Indoors

Vocabulary: Decomposition, detritivores, limiting factor, soil formation

Objective:
1. Students will describe how temperature affects decomposition in tundra ecosystems.

Teaching Strategy:
In an experiment, students expose organic material to freezing temperatures and examine the effects.

Complementary Activities:
"Permafrost" and *"Rotting in the Cold Tundra"* in this section; *"Rooting in the Bright Tundra"* and *"Rooting in the Cold Tundra"* in *Section 3, Adaptations***.**

Materials:
4 potatoes, 2 containers, labels, small food or postage scale, place to freeze 2 potatoes.

Background:
See *INSIGHTS Section 2, Topography and Soil: "Cold and Decomposition."*

Procedure:
1. Students will carefully observe their experiments and record their observations in journals.

2. Discuss the significance of **decomposition** in **soil formation**, plant growth, and a healthy food web. Describe the experiment that will follow. Ask students to predict which potato will decay first: a frozen and then thawed one or a nonfrozen one. Students should suggest reasons for their answers and record their predictions and reasons in their journals.

3. Weigh 2 potatoes and then freeze them. Allow them to thaw. Weigh them again. Weigh 2 nonfrozen potatoes. How do they all compare?

4. Compare one frozen potato with one non-frozen potato. Squeeze both potatoes. Did water come out of both? Where did the water come from? *(A living cell contains about 85 to 90 percent water. When water inside the cell freezes and expands, the cell walls break.)*

5. Place an unsqueezed frozen-thawed potato in a container and label it. Place an unsqueezed nonfrozen potato in another container and label it. Each day for 2 weeks record the changes in the potatoes.

6. At the end of the experiment, students discuss their results in class. Ask students to summarize their observations and think of their experiment results in terms of the tundra environment. Discussion questions include:
• Why is freezing important to decomposition?
• What are the rates of decomposition in tundra environments?
• Do these processes occur faster or slower than in warmer environments?
• How might the rate of decomposition affect plant growth and the number of animals living in a particular environment?

Evaluation:
Students write a summary of the ways temperature affects the recycling of nutrients and explain why tundra soil is less rich than soil in other environments.

Credit:
Adapted from *Yukon Environmental Handbook, Part One: Small Winter Lif*e, Yukon Department of Education. Whitehorse, Yukon, Canada, 1982.

Curriculum Connections:
(See appendix for full citations)

Books:
A Naturalist's Guide to the Arctic (Pielou) 9-12

One Small Square: Arctic Tundra (Silver)

Tundra (Sayre)

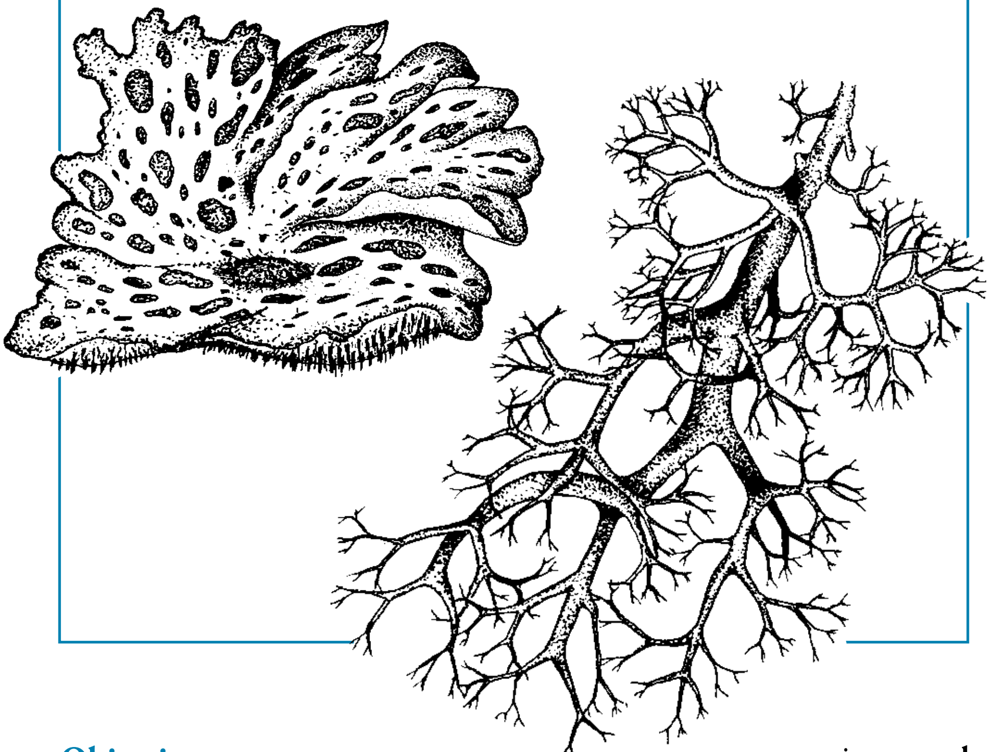
Websites:
Alaska Science Forum
<www.gi.alaska.edu/ScienceForum>

Alaska Statewide Databases <sled.alaska.edu>

Teacher Resources:
(See appendix)

Lichen Soil Builders

5 EXTENSIONS



Section 2
TUNDRA ACTIVITIES

Grade Level: 4 - 6

NGSS: MS-LS2-2

Subject: Science

Skills: Observing, classifying, discussing, generalizing

Duration: 45 minutes

Group size: 1-4

Setting: Indoors or outdoors

Vocabulary: Alga-algae, colonize, crustose, filamentous, foliose, fruticose, fungus-fungi, lichen, photosynthesis, pioneer, soil formation, symbiosis

Objective:

1. Students will find and classify 3 or 4 forms of lichens.

2. Students will explain how lichens often begin the soil-forming process.

Teaching Strategy:

Students search their surroundings for lichens and record their observations.

Complementary Activities:

"Lichens and Acid Rain," in *Section 5, Human Impacts.*

Materials:

Pencil, paper, pictures of different types of lichens.
OPTIONAL: clipboard.

Background:

See *INSIGHTS Section 2, Topography and Soil: "Lichen Soil Makers.*

Procedure:

1. Discuss the teamwork (**symbiotic** relationship) of **algae** and **fungi** that creates **lichens** and that enables these organisms to **colonize** areas such as rocks and dead trees.

2. Describe 4 forms of lichen:
crustose – patchy and crusty (growing on bare rock)
foliose – curling and leafy (growing on the ground and wood)
fruticose – branching and mossy (growing on the ground and wood)
filamentous – stringy and beardlike (hanging from trees)

3. OUTDOORS, students look for lichens. Students record in their journals what kind of places the lichens have colonized. Students note if any other plants are growing next to the lichens or if they are early **pioneers.** Note if sand or plant debris are trapped within the lichens as the start of **soil formation**.

4. Looking closer, students should sketch in their journals the structure, or form, of each lichen and make notes on the type of surface where each is growing.

5. Ask the students to identify each sample as one of the 4 forms, and ask them to comment on where lichens were found growing.

6. Discuss the role that the lichens play in the local ecosystem. Can students make some generalizations about where each lichen form tends to grow? How do lichens affect their surroundings?

Evaluation:

1. Describe how the actions of lichens contribute to soil formation in northern ecosystems.

2. Name each type of lichen.

EXTENSIONS:

A. **Make a lichen field guide.** Students make a field guide of lichens, including colorful pictures and descriptions. Classify each lichen into one of the 4 categories.

B. **Rehydrate a lichen.** Using only one small sample, preferably from an already broken lichen, place a dry lichen piece into a jar of water for 5 to 10 minutes. Watch it expand into a beautifully fresh-looking plant. Discuss the role of the **fungi** in absorbing and holding most of the water needed by the **algae** for **photosynthesis**.

C. **Write lichen poems.** Write a short poem about a favorite lichen and why it is important. Poems can be free verse or rhyming. See Project WILD's "Animal Poetry" for ideas about haiku, cinquain, diamante, and group poems.

D. **Write a story.** Write stories from a lichen's point of view.

E. **Design a lichen poster.** Design a poster illustrating the different forms of lichens and/or how lichens contribute to soil formation.

Curriculum Connections:

(See appendix for full citations)

Books:

A is for Arctic (Lynch)

The Arctic Land (Kalman)

One Small Square: Arctic Tundra (Silver)

Tundra (Kaplan)

Websites:

Alaska Science Forum
<www.gi.alaska.edu/ScienceForum>

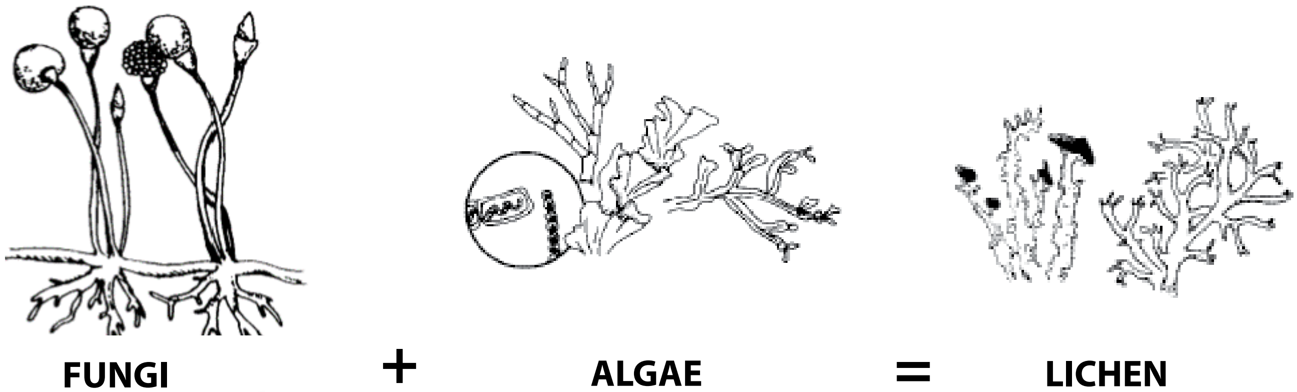
Lichen photos and information <www.ucmp.berkeley.edu/fungi/lichens.html>
(University of California Museum of Paleontology)

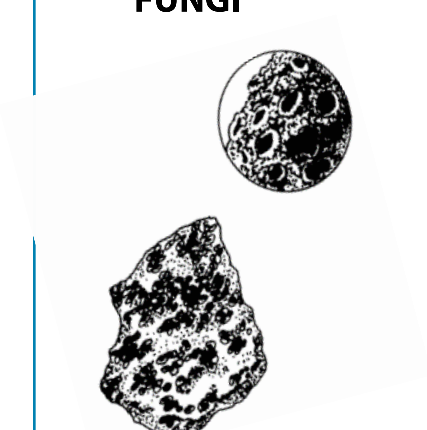
Teacher Resources:

(See appendix)

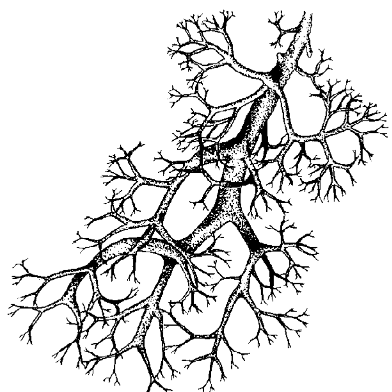
What one word fills all these spaces?
__________split rocks.
__________have no leaves.
__________have no flowers.
__________have no roots.
__________have no stems.
__________are really 2 life forms called algae and fungi living symbiotically.
__________of at least 2500 kinds grow in the Arctic.

Fill in all these spaces with the amazing <u>LICHENS</u>.

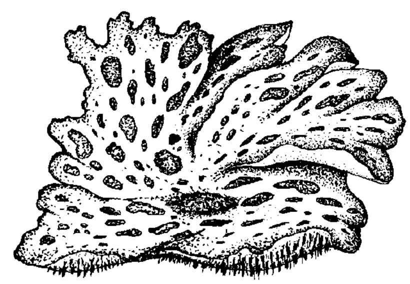




Crustose lichens look like a crust on the surface of rocks and wood.



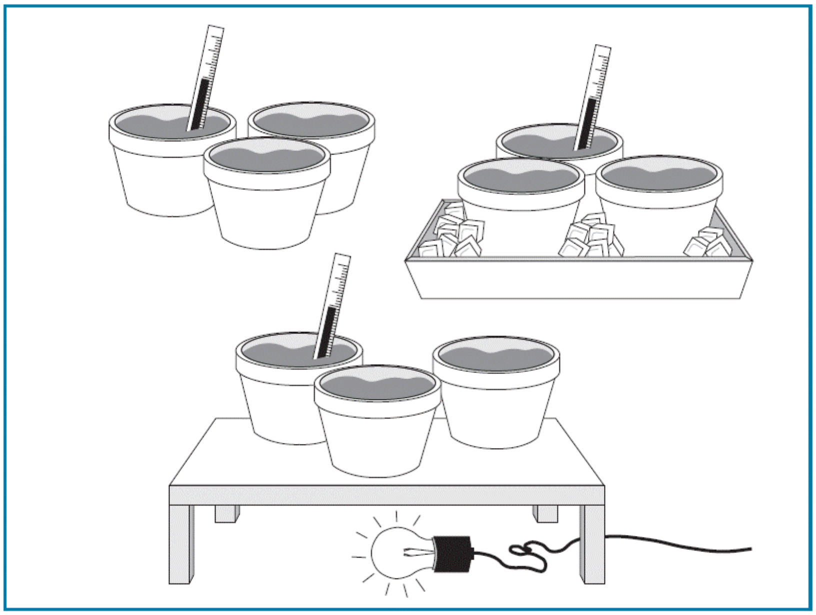
Fruticose lichens look like tiny shrubs or trees.



Foliose lichens look like large leaves.

Growth and Cold

1 EXTENSION



Section 3
TUNDRA ACTIVITIES

Grade Level: K - 3

NGSS: K-LS1-1. -LS2-1, 3-LS3-2.

Subject: Science

Skills: Predicting, analyzing, observing, measuring

Duration: Several classes over two weeks

Group Size: Whole class

Setting: Indoors

Vocabulary: Cold, hypotheses, temperature, tundra, warm

Objective:

Students will be able to state how cold temperatures affect plant life and growing seasons.

Teaching Strategy:

Students perform an experiment to test plant growth under different temperatures.

Complementary Activities:

"Decomposition and Cold" in *Section 2, Tundra Topography and Soil.*

Materials:

Water, soil, pans, light bulb, ice, bean seeds in small pots (at least 3), thermometers, journals or class chart.

Background:

See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:

1. Review procedures for using thermometers and reading temperatures.

2. Students keep a daily log of their investigation. Younger students may draw pictures to record their observations. For older students, each page should include the date, the subject, a drawing of the investigation or the results, and 2 or 3 sentences describing the changes observed.

3. Plant bean seeds in pots. Divide the pots into three groups. Keep the plant pots, soil, light, and watering schedules identical for each plant.
• Put some of the plant pots in a pan containing ice.
• Put other plant pots at room temperature.
• Place a light bulb underneath a large pan containing the remaining plant pots to create a warmer environment.

4. Record students' **hypotheses** (*assumptions*) about what will happen to the seeds in the three groups.

5. Measure the temperature of the soil in each plant pot at least twice during the course of the investigation.

6. Keep a class record of observations about the growth (or lack of growth) of the plants for two weeks. Use individual journals or a class chart for records.

7. Hold a class discussion and list possible reasons why some plants grew faster than others.

8. Apply what students have learned to the growing seasons in high latitude and alpine tundra. What is the growing season for plants in your community?

Evaluation:
Students describe how cold affects plant growth.

EXTENSION:
Keep a calendar of plant growth. As spring approaches, keep a class calendar of daily high and low temperatures. Make a contest challenging students to observe the first sign of new plant growth. Correlate the date of observation of the first new growth with rises in daily temperatures.

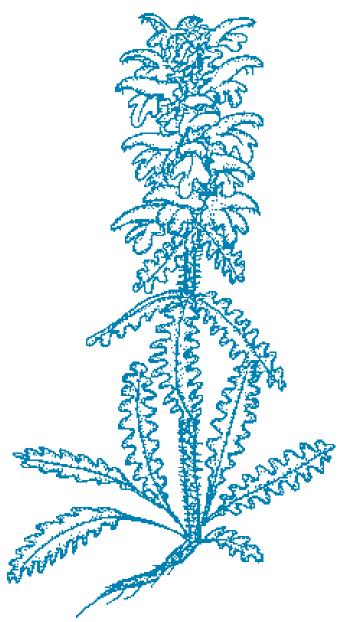
Credit:
This activity was modified by Jean Seaton, primary teacher from Chignik Lagoon.

Curriculum Connections:
(See appendix for full citations)

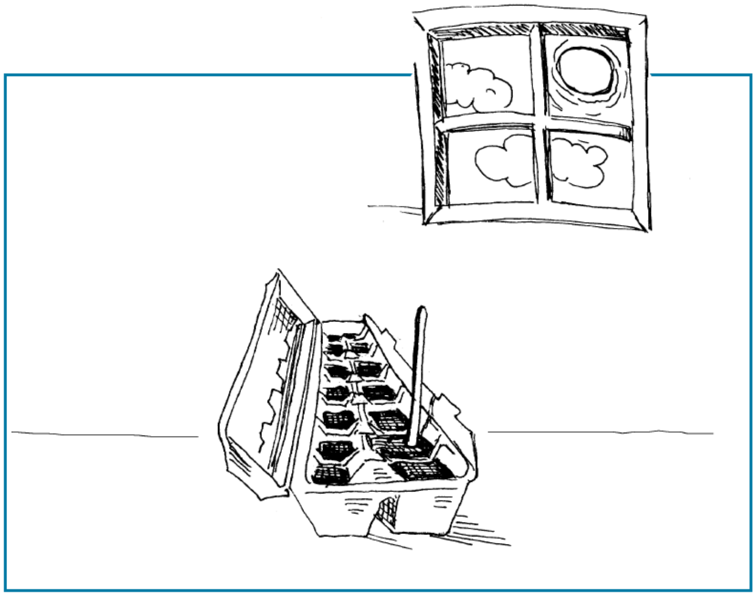
Books:
Arctic Tundra: Land with No Trees (Fowler)

This Place Is Cold (Cobb)

Teacher Resources:
(See appendix)



Rooting in the Bright Tundra



Section 3
TUNDRA ACTIVITIES

Grade Level: 3 - 12

NGSS: 3-LS3-2.,MS-LS1-5 MS-LS2-1.,MS-LS2-4, HS-LS1-5. HS-LS2-1.,HS-LS2-3.

Subject: Science

Skills: Observing, comparing, inferring, predicting

Duration: Several short lessons over two weeks

Group Size: Whole class or small group

Setting: Indoors

Vocabulary: Herbivores, light, limiting factor, photosynthesis

Objective:
Students will describe how light affects growth in tundra ecosystems.

Teaching Strategy:
In an experiment, students expose seeds to various levels of light and examine the effects.

Complementary Activities:
"Rooting in the Cold Tundra" in this section. *"Rotting in the Cold Tundra"* and *"Rotting and Freezing,"* both in *Section 2, Tundra Topography and Soil.*

Materials:
Each station or group needs several bean seeds, potting soil, water, two egg cartons or small pots, two grow lights or incandescent lights (classroom lights).

Background:
See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:
1. Discuss why plants need **light *(photosynthesis)***. Ask students if the amount of light a plant receives will affect its growth. Will a plant grow slowly or quickly if it receives little light? What if it receives more light?

2. Ask students to predict what will happen to plants growing under 8 hours of light compared with plants growing under 4 hours of light. Students record their predictions in their journals.

3. Fill each egg carton compartment with potting soil. Place one bean seed in each. Lightly water the seeds, then cover the soil with plastic wrap. Place one container under grow light #1. Place the other container under grow light #2.

4. Control the amount of light received by the plants. Leave grow light #1 on throughout the school day. Turn it on in the morning, and turn it off before going home. Turn grow light #2 on with #1, but turn it off at lunch. That way, the plants under grow light #2 will receive only half as much light as those under grow light #1.

5. For the next 2 weeks, students carefully observe the plants in the egg carton and record their observations in a journal. They should draw pictures of all the plants under each grow light every other day and measure their height every other day.

6. At the end of the two weeks, students discuss their experiments in class. Ask students to summarize their observations and compare the results to the tundra environment. Raise the following questions:

- What are the rates of plant growth in tundra environments?
- Do these processes occur more quickly or more slowly than in warmer environments? Consider the long sunlight of the arctic summer. Contrast the growth rate in the arctic winters. Which would be a **limiting factor**?
- The number of **herbivores** living in an area depends upon the amount of food produced by the plants in the area. Which area would have more herbivores living in it: a square mile of land at a high latitude, or a square mile of land at a low latitude?
- How might the rate of plant growth affect the number of other animals living in the tundra? Is plant growth a limiting factor?

Evaluation:

Students write a summary of the ways light affects the tundra ecosystem and explain why tundra environments support fewer animals than do other environments.

Curriculum Connections:

(See appendix for full citations)

Books:

A Naturalist's Guide to the Arctic (Pielou)

One Small Square: Arctic Tundra (Silver)

Tundra (Kaplan)

Tundra (Sayre)

Websites:

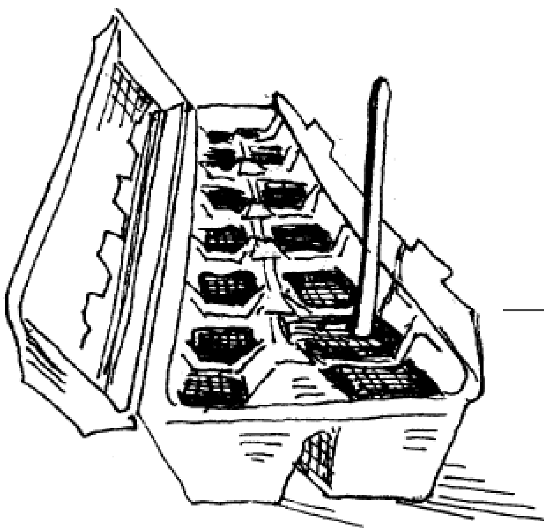
Alaska Science Forum website
<www.gi.alaska.edu/ScienceForum>

Teacher Resources:

(See appendix)

**Is it always cold in the tundra?
Warm – even hot – temperatures can occur every day in high-elevation tundra environments.**

Rooting in the Cold Tundra



Section 3
TUNDRA ACTIVITIES

Grade Level: 3 - 12

NGSS: 3-LS3-2., MS-LS1-5, MS-LS2-1., MS-LS2-4. HS-LS1-5., HS-LS2-1.

Subject: Science

Skills: Observing, comparing, in ferring, predicting

Duration: Several short lessons over two weeks

Group Size: Whole class or small group

Setting: Indoors or outdoors

Vocabulary: Decomposition, herbivores, limiting factor, soil formation, temperature

Objective:
Students will describe how temperature affects growth in tundra ecosystems.

Teaching Strategy:
In an experiment, students expose seeds to various temperatures and examine the effects.

Complementary Activities:
"Rooting in the Cold Tundra" in this section. *"Rotting in the Cold Tundra"* and *"Rotting and Freezing,"* both in *Section 2, Tundra Topography and Soil.*

Materials:
Each station or group needs several bean seeds, potting soil, water, an egg carton or small pots, and thermometers.

Background:
See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:
1. Ask students to predict how **temperature** affects plant growth or the decay of organic material? What is the relationship among temperature, plant growth, and **decomposition** *(recycling of nutrients)*? Record predictions in journals.

2. Divide an egg carton in half, then fill each compartment with potting soil. Place one bean seed in each, except for one (*this will be used to measure soil temperature*). Lightly water the seeds, then cover the carton with plastic wrap.

3. Place one container in a warm, lighted spot. Place the other container in a cold, lighted spot or on top of a pan of ice. (*If you place it on a pan of ice, be sure to replace the ice daily.*)

4. Students observe the experiment carefully over the next 2 weeks. They record temperatures of both the air and soil, if possible. They record their observations every other day with written descriptions and drawings. They measure and record plant growth every other day.

5. At the end of the 2 weeks, students discuss their experiments in class. Ask students to summarize their observations and compare the results to the tundra environment. Raise the following questions:

- What are the rates of plant growth in tundra environments?
- Do these processes occur more quickly or more slowly than in warmer environments? Consider the long sunlight of the arctic summer. Contrast the growth rate in the arctic winters. Which would be a limiting factor?
- The number of **herbivores** living in an area depends upon the amount of food produced by the plants in the area. Which area would have more herbivores living in it: a square mile of land at a high latitude or a square mile of land at a low latitude?
- How might the rate of plant growth affect the number of other animals living in the tundra? Is plant growth a limiting factor?
- What are the rates of decomposition in tundra environments?
- Do these processes occur more quickly or more slowly than in warmer environments?
- How might the rate of decomposition affect plant growth and the number of animals living in a particular environment?

Evaluation:

Students write a summary of the ways temperature affects the tundra ecosystem and explain why tundra environments support fewer animals than do other environments.

Curriculum Connections:

(See appendix for full citations)

Books:

A Naturalist's Guide to the Arctic (Pielou) 9-12

One Small Square: Arctic Tundra (Silver)

Tundra (Kaplan)

Websites:

Alaska Science Forum website
<www.gi.alaska.edu/ScienceForum>

Teacher Resources:

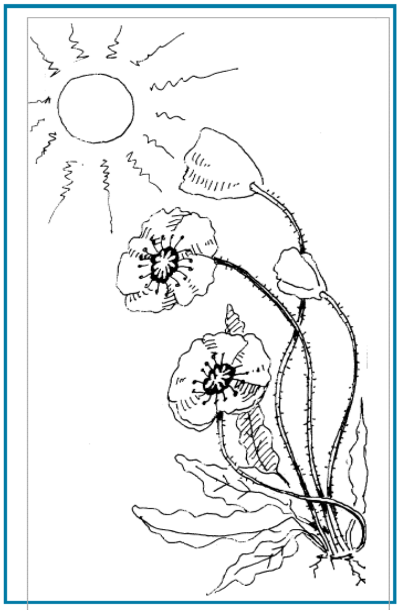
(See appendix)

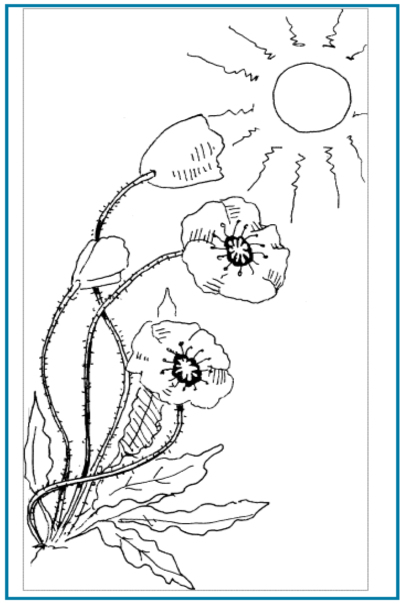
WE'RE AFFECTED BY COLD AS WELL!

"Goose bumps" appear on our skin when we are chilled. Why? Biologists theorize that when humans were hairy creatures, "goose bumps" helped us fluff up our body hair to trap air and insulate us from the cold. We've lost the hair, but kept the fluffing mechanism – "goose bumps."

Flower Flip Book

1 EXTENSION **ALERT: ALASKA ECOLOGY CARDS OPTIONAL**





Section 3
TUNDRA ACTIVITIES

Grade Level: K - 3

State Standards: Art A-2

NGSS: K-LS1-1., 3-LS3-2.

Subjects: Science, art

Skills: Comparing, classifying, fine motor coordination

Duration: 45 minutes

Group Size: Whole class, individual

Vocabulary: Adaptations, dormant, heliotropic

Objective:
Students will explain one tundra plant adaptation.

Teaching Strategy:
Students make a flip book that shows a flowering plant "following" the sun.

Complementary Activities:
"Plan Your Tundra Plant" and *"Draw Your Tundra Animal,"* both in this section.

Materials:
Copies of the "Flowers Flip Book" *(following pages)* for each student (heavyweight paper is recommended for these copies), pencils, crayons, colored pens, stapler, butcher paper.

Pictures of flowering tundra plants from magazines, the *Tundra INSIGHTS Section 3,* or the *Alaska Ecology Cards:*

Moss campion, dryas, woolly lousewort, bearberry, heather, lingonberry, harebell, arctic poppy, avens, forget-me-not, hairy mile vetch, Lapland rosebay, Lapland diapensia, rock jasmine, northern primrose, wedge-leafed primrose, Arctic douglasia, northern shooting star, alpine saxifrage, Arctic lupine, Arctic cinquefoil, purple saxifrage, draba, buttercup, anemone.

Background:
See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:
1. Discuss tundra plant adaptations with the students.

2. Put pieces of butcher paper on the wall and label each piece with a flowering plant adaptation. Suggestions are:
Adaptation: Tundra plants stay tiny to avoid the wind.
Adaptation: Tundra plants grow hairy to trap heat.
Adaptation: Tundra flowers grow in dark colors to absorb heat and stay warm.
Adaptation: Tundra plants follow the sun to absorb the sun's energy.
Put one picture of each adaptation on the appropriate piece of butcher paper as a guide.

3. Pass out flowering plant pictures to every student. Several photographs or drawings of the same plant may be used

so that each student has one plant picture.

4. Ask students to fasten their pictures to the most appropriate piece of butcher paper to build a picture bulletin board of many flowering tundra plants that share similar adaptations.

5. Explain that the flip book they will work on is about one of these adaptations: the "follow-the-sun" or **heliotropic** adaptation *(see "Color,"* INSIGHTS *Section 3).*

6. Students complete the flower flip book panels by drawing a bowl-shaped flower in each panel. The bowl-shaped flower should always face the sun. Encourage students to look at the "follows-the-sun" butcher paper on the wall if they are unsure about drawing the flower. Color the flowers, leaves, and sun.

7. Students cut apart the panels. Arrange in the correct time sequence. Staple together at the left side.

8. Flip through the book – holding it by the stapled edge – and enjoy the moving picture.

Evaluation:
Students describe the tundra plant adaptation of "following the sun" to the teacher.

EXTENSION:
Adapted to low precipitation. Imagine a plant that lives in an environment that is dry most of the year. What would some of the adaptations be for that plant? "Build" the plant by drawing it as students suggest the adaptations.

Credits:
Adapted from "Flowers Follow the Sun" by Barbara Molyneaux-Wild, *Arctic Ecology: Elementary Leve*l, The Imaginarium Science Discovery Center, Anchorage, AK, 1994.

Curriculum Connections:
(See appendix for full citations)

Books:
A is for Arctic (Lynch)

Arctic Tundra: Land with No Trees (Fowler)

Discovering Wild Plants: Alaska, Western Canada, the Northwest (Schofield)

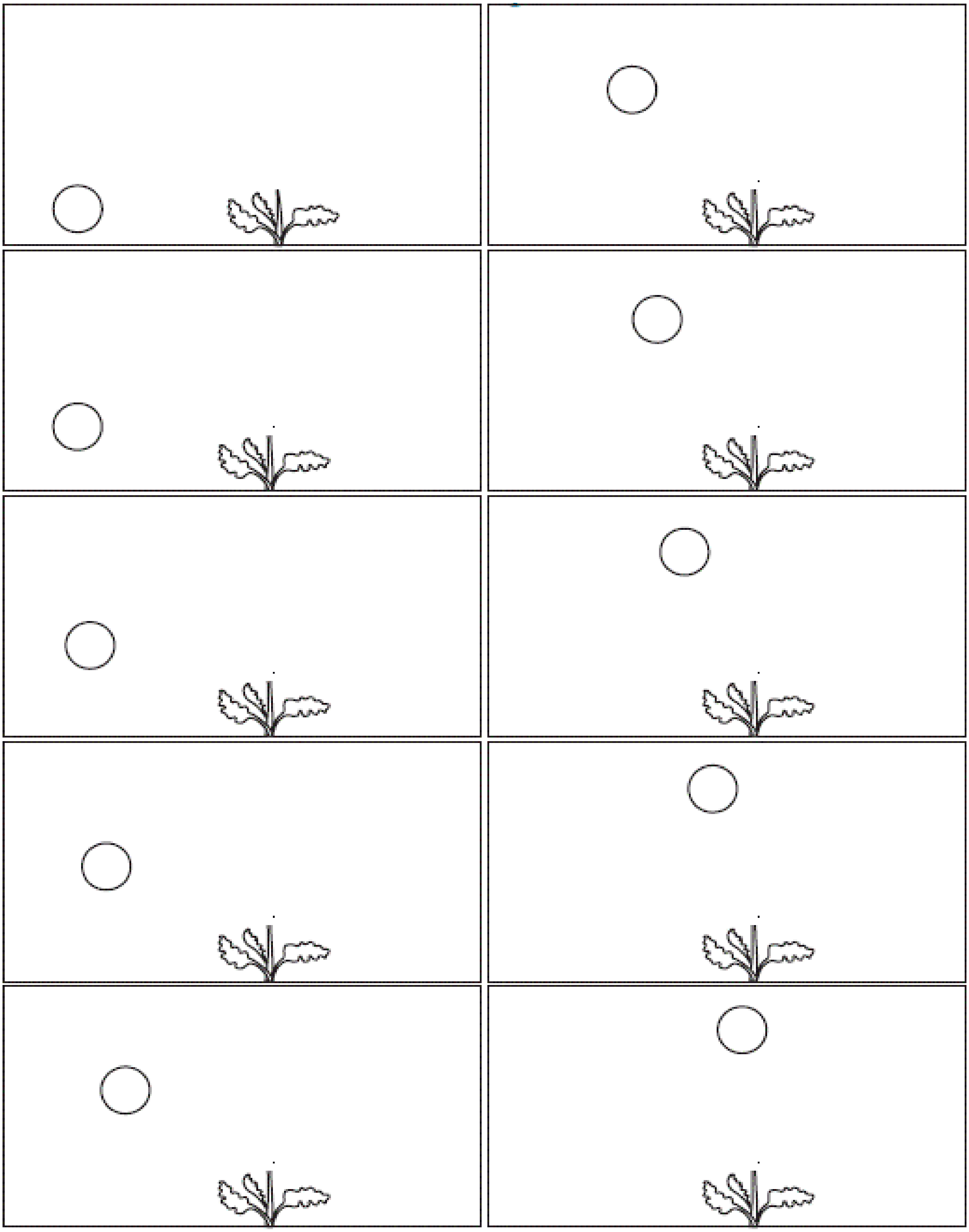
Field Guide To Alaskan Wildflowers (Pratt)

One Small Square: Arctic Tundra (Silver)

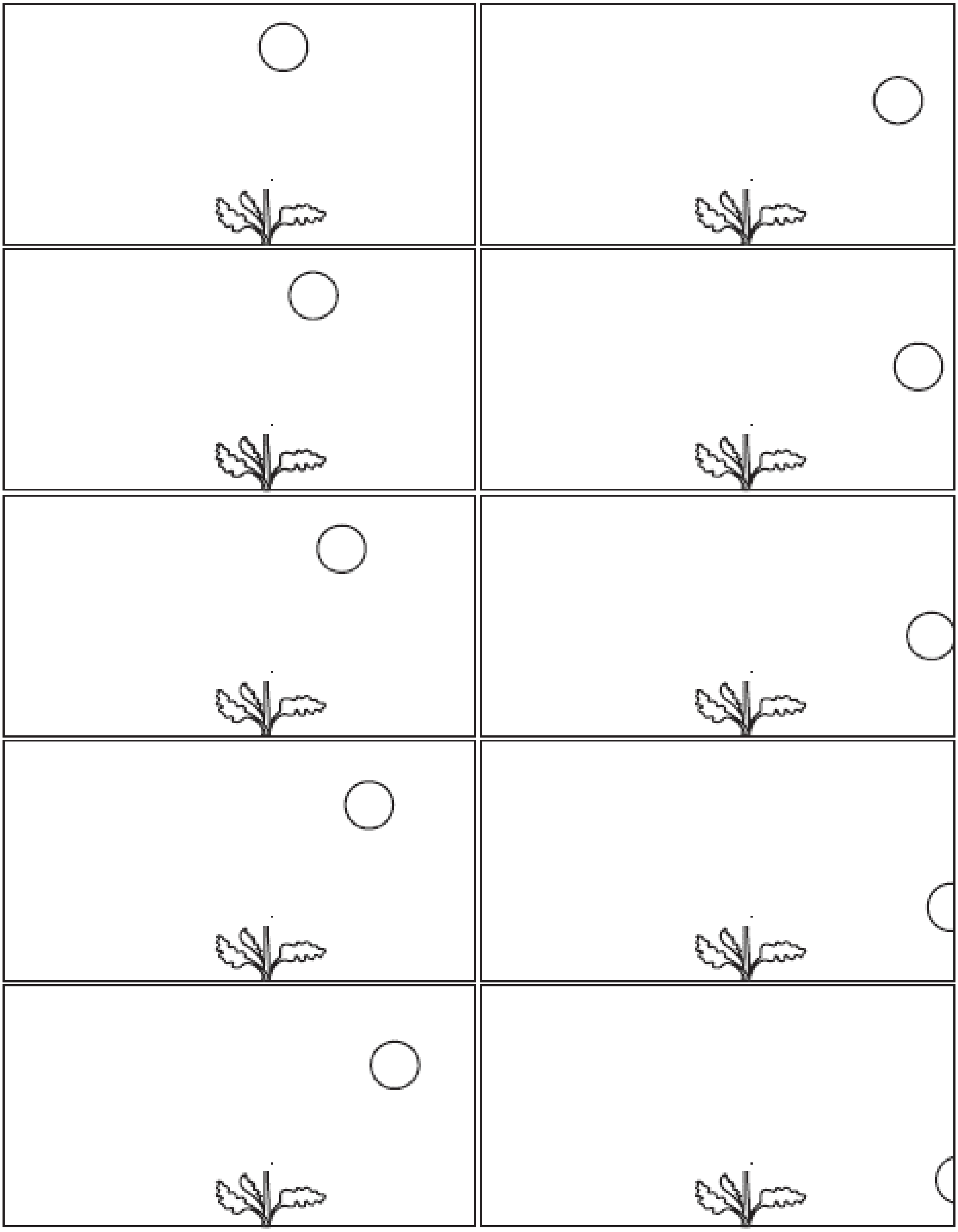
Teacher Resources:
(See appendix)

The 2-inch (5 centimeter) tall tundra plant, moss campion, may be 50 years old!

Flower Flip Book

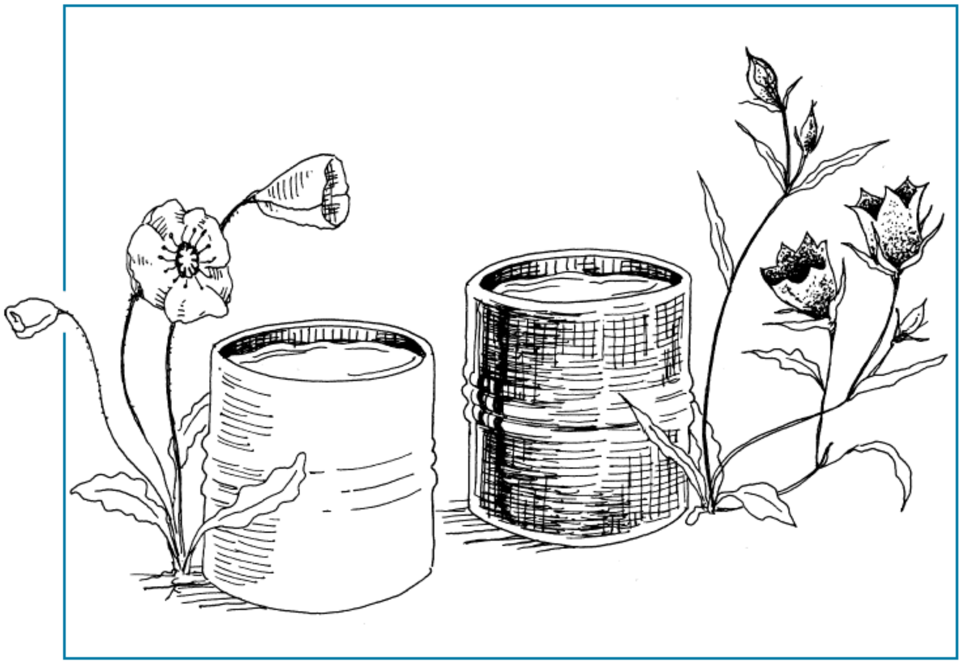


Flower Flip Book



Tundra Adaptations

4 ACTIVITIES and 1 EXTENSION



Section 3
TUNDRA ACTIVITIES

Grade Level: K - 9

State Standards: SL.K.4, SL.1.4 SL.2.4, SL.3.4, SL.4.4.5.4

NGSS: 3-LS3-2., MS-LS4-4, HS-LS4-4.

Subjects: Science

Skills: Measuring, comparing, inferring, predicting, hypothesizing, reading, speaking

Duration: 30 minutes for experiments, additional time for discussion

Group Size: 3-4 students
Setting: Indoors or outdoors
Vocabulary: Adaptations, hypothesis, thermometer

Objective:

Students will demonstrate that living things in tundra ecosystems have special adaptations that enable them to survive the cold.

Teaching Strategy:

Students conduct 4 investigations to determine the effects of color, size, and shape on heat loss and use the results of their investigations to explain some of the physical characteristics of tundra animals.

Complementary Activities:

"Plan Your Tundra Plant" and *"Draw Your Tundra Animal,"* both in this section.

Materials:

Copies of the "Adaptation Cards" *(following pages)*; each group of students will need the materials and instructions for *one* of the following experiments:

1 - Color and Heat Absorption:
2 identical tin cans, 1 painted black and 1 painted white; 2 thermometers; cool water; direct, bright sunlight or an intense grow-light; Science Card.

2 - Color and Heat Loss:
2 identical tin cans, 1 painted black and 1 painted white; 2 thermometers; hot water; Science Card.

3 - Size and Heat:
2 thermometers, large and small containers made of the same material (pails, cans, or plastic food containers), hot water, access to outdoors or a refrigerator, Science Card.

4 - Long Ears and Heat:
1 pair rubber or plastic gloves, several rubber bands, 2 thermometers, pail of warm water, measuring cup, Science Card.

Background:

See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:

IN ADVANCE, set up 4 (or more) stations as described in the following Science Cards. Repeat some stations if class size is large. Post the Science Cards at each station.

VARIATION FOR YOUNGER STUDENTS
Demonstrate each experiment prior to allowing independent investigation. Teach students how to use and care for **thermometers**. Define and discuss **hypothesis.**

1. Either have all groups do all 4 activities, or have separate groups do separate activities and report their findings to the class. Each experiment requires 20-30 minutes with a 15-minute wait for results. You may wish to plan a time filler for this wait period. Groups record the data from their investigations.

2. Each group presents the results of its investigations. Student reports should include their hypotheses, methods, results and conclusions. Use the questions provided at the end of each investigation task card to help students interpret their results in terms of animal adaptations.

Evaluation:
Give students a set of tundra animal drawings (Alaska Ecology Cards or "Tundra Adaptation Cards") or a list of tundra animals such as tundra hare, arctic fox, lemming, ptarmigan, or caribou. Students state verbally or in writing the animal's adaptations for the tundra environment.

EXTENSIONS:
Design more adaptation experiments. Working with partners, students design other experiments to determine how arctic animals adapt to their cold environments. Use the same variables from this activity (size, long ears, and color), or lead students in brainstorming for other ideas. Depending on grade level, students write the background and procedure for their activity, using the format from this activity, and conduct the experiment or its simulation.

Curriculum Connections:
(See appendix for full citations)

Books:
A is for Arctic (Lynch)

Above the Treeline (Cooper)

Animals in Winter (Bancroft)

Arctic Tundra (Forman)

Arctic Animals (Kalman)

A Caribou Journey (Miller)

Flight of the Golden Plover (Miller)

One Small Square: Arctic Tundra (Silver)

Polar Bear Journey (Miller)

Polar Mammals (Brimmer)

Tundra Discoveries (Wadsworth)

Welcome to the Ice House (Yolen)

Teacher Resources:
(See appendix)

SCIENCE CARD

Color and Heat Absorption

Materials:

You need 2 tin cans the same size, one painted black and one painted white; 2 thermometers; cool water; direct, bright sunlight or an intense grow-light; and this Science Card.

Question?

Which coat do you think would be warmer: a black coat or a white coat? State your answer as an **hypothesis** that you could test. This investigation will help you test your hypothesis.

1. Fill each of the cans with the cool water.

2. Measure and record the temperature of the water.
Starting Temperature of Water: ________

3. Place both cans outside in bright, direct sunlight or underneath a bright grow-light.

4. Look at the cans after 15 minutes. Measure and write down the water temperature in each can. If there is no difference, put them back under the light and wait another 15 minutes.
Ending Water Temperature in Black Can: ________
Ending Water Temperature in White Can: ________

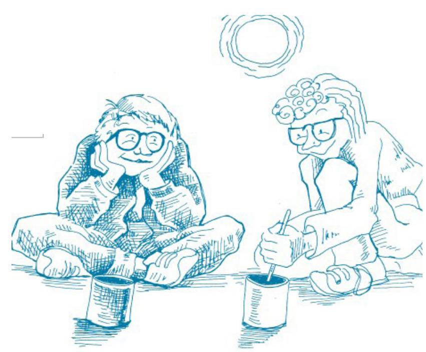
5. Based on this experiment, can you accept or reject your hypothesis? Would a black or white coat be warmer?

6. Based on the results of this experiment, what color coat do you think tundra animals would have in order to stay warm?

7. Think carefully about the insects, plants, and animals of alpine and lowland tundra. Are most of them the color you predicted?

Why do you think most of the insects occurring in tundra regions are darker than insects living in warmer environments?

Why are many of the birds and mammals that remain in the tundra environment year-round white? Can you think of some other advantages a light-colored animal has in the snow?



SCIENCE CARD

Color and Heat Loss

Materials:

You need 2 tin cans the same size, one painted black and one painted white; 2 thermometers; hot water; and this Science Card.

Question?

Which do you think would be a warmer coat – a black one or a white one? State your answer as an **hypothesis** that you could test. This experiment will help you test your hypothesis.

1. Fill each can with hot water.

2. Measure and record the temperature of the water.
Starting Temperature of Water ________

3. Place both cans outside in a dark or shaded place.

4. Wait about 15 minutes. Check the 2 cans. Measure and write down the temperature of the water in each can. If there is no difference, replace them outside and wait another 15 minutes.

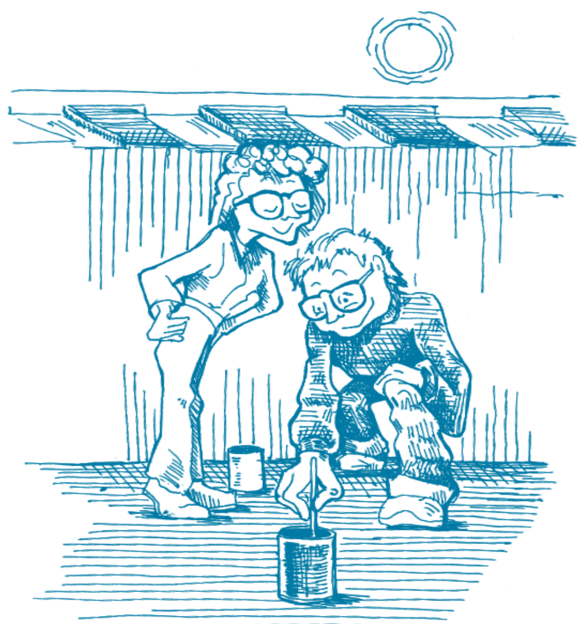
Ending Water Temperature in Black Can _______
Ending Water Temperature in White Can _______

5. Based on this experiment, can you accept or reject your hypothesis? Would a black or white coat be warmer?

6. Based on the results of this experiment, what color coat do you think tundra animals would have in order to stay warm?

7. Think carefully about the insects, plants, and animals of alpine and lowland tundra. Are the majority of them the color you predicted?

Why do you think many tundra insects are darker than insects that live in warmer environments? Why do you think many of the birds and mammals that live in tundra regions year-round are white?



SCIENCE CARD

Size and Heat

Materials:

2 thermometers, large and small containers made of the same material (*pails, cans, or plastic food containers*), hot water, access to outdoors or a refrigerator, "Adaptation Cards," and this Science Card.

Question?

Which do you think loses heat (gets cold) more quickly: a large object or a small object? Write down your guess as an **hypothesis**. Find out if your hypothesis is correct with this experiment.

1. Fill a large pail and a small pail with hot water. Measure the temperature of the water in each pail and write it down.
Starting Water Temperature in Large Pail _____
Starting Water Temperature in Small Pail _____

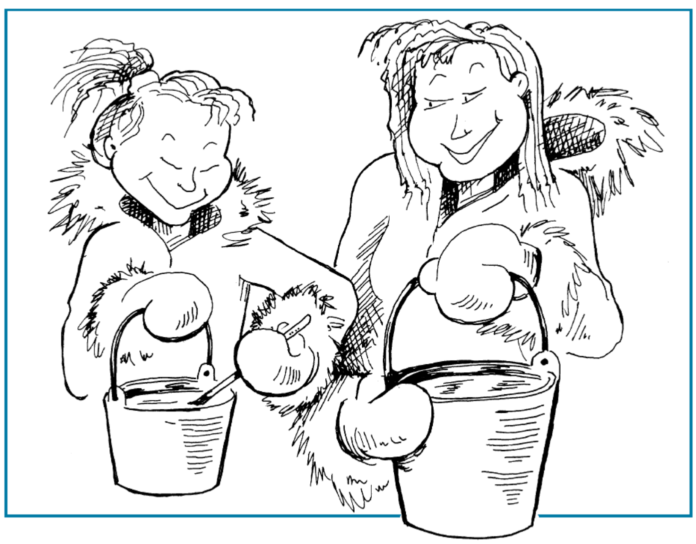
2. Place both pails outside or in a cold place for 15 minutes. Then measure the water temperature in each pail again. Record these measurements.
Ending Water Temperature in Large Pail _____
Ending Water Temperature in Small Pail _____

3. Subtract the ending temperature from the starting temperature and record your answers.
Starting minus Ending Temperature in Large Pail = ________
Starting minus Ending Temperature in Small Pail = ________

Which pail cooled down more? Which lost heat more quickly, the large one or the small one? Did your prediction match your results?

4. Based on what you discovered about the relationship between cooling and the size of objects, do you think animals living in tundra environments would be larger or smaller than animals living in warm environments?

5. Using the "Adaptation Cards," compare the sizes of the arctic fox and kit fox, arctic ground squirrel and antelope ground squirrel, lemming and jumping mouse, snowy owl and great horned owl. Which animal in each of these pairs is largest – the one living in tundra or the one living in a warm environment? Which do you predict would be larger, the moose in Wyoming or moose in Alaska? Research to learn if you are correct.



Long Ears and Heat

Materials:

1 pair rubber or plastic gloves, several rubber bands, 2 thermometers, pail of warm water, measuring cup, "Adaptation Cards," and this Science Card.

Question?

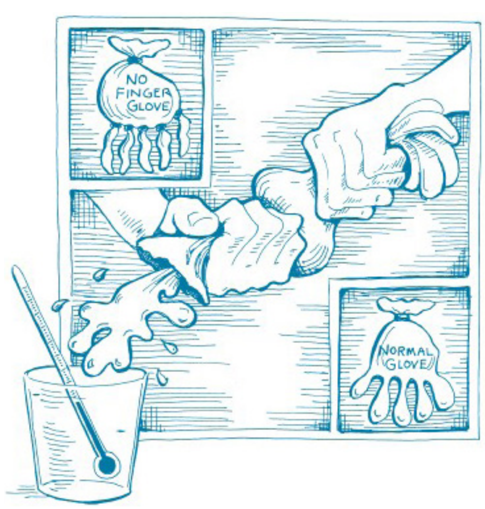
Which do you think keeps your hands warmer – gloves (*with separate places for each finger*) or mittens? State your answer as an **hypothesis**. You can discover which is warmer by running a test.

1. Take a pair of rubber gloves. Use rubber bands to close off the 5 finger compartments in one of the gloves. Be sure the rubber bands are tight. This will be called the "No-Finger Glove." The other glove will be called the "Normal Glove."

2. Get a pail of warm water and measure the temperature of the water. Write this measurement below.
Starting Temperature of the Water ________

3. Now measure 1 cup of this water and pour it into the "No-Finger Glove." Close the top of the glove with another rubber band. Be sure to close it tightly, so it won't leak.

4. Measure another cup of the water and pour this into the "Normal Glove," so that water runs into the finger compartments. Close the top of this glove with another rubber band. Again, be sure to close it tightly so it won't leak.



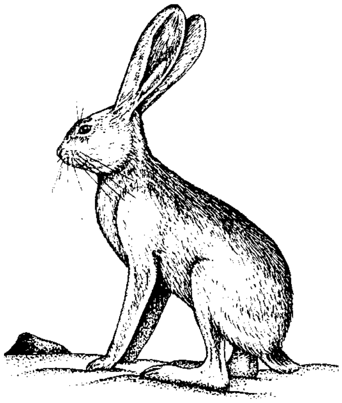
5. Place both gloves outside or in a cold place, near each other but not touching. Wait 15 minutes, then bring them both inside. Pour the water from the "No Fingers Glove" into one cup and the water in the "Normal Glove" into another cup. Quickly, measure the temperature of the water in both cups. Record your answers:
Ending Temperature of water from "No-Finger Glove" ________
Ending Temperature of water from "Normal Glove" ________

6. In which glove did the water get colder? How would you explain this difference? Next time it's cold and you go outside, will you wear mittens or gloves to keep your hands warm?

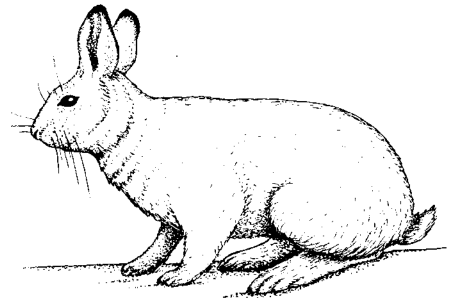
7. Now think about animals living in the tundra. The blood in their bodies is like the water in the gloves. Their toes, ears, and tail are like the fingers in a glove. Considering what you know about gloves and water temperature, which animal do you think would stay warmer in the tundra, one with long ears, toes, and tail, or one with short ears, toes, and tail?

8. Compare the ears of the arctic fox to those of the kit fox, and the ears of the tundra hare to those of the desert jackrabbit (shown on the "Adaptation Cards"). Give a reason for the differences you observe?

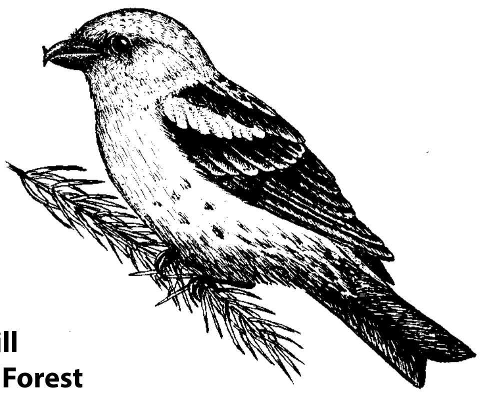
Tundra Adaptation Cards



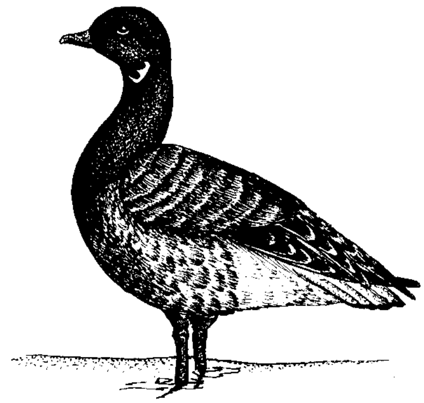
Desert Jackrabbit
Desert



Snowshoe Hare
Tundra

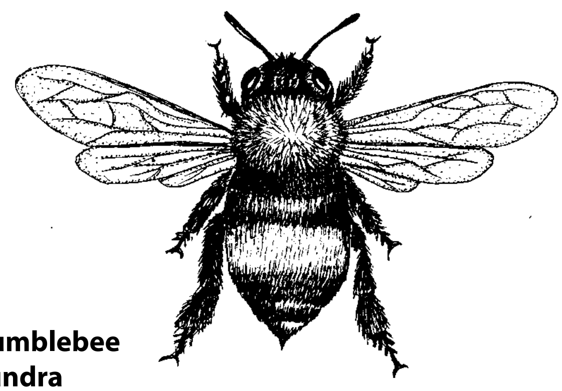


Crossbill
Spruce Forest



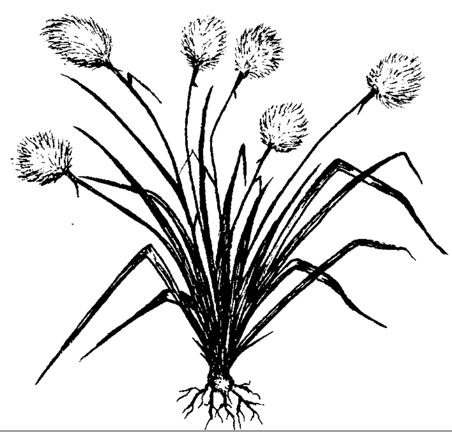
Brant Goose
Tundra

Honeybee
Forest, Desert



Bumblebee
Tundra

Trumpet Flower
Tropical Forest

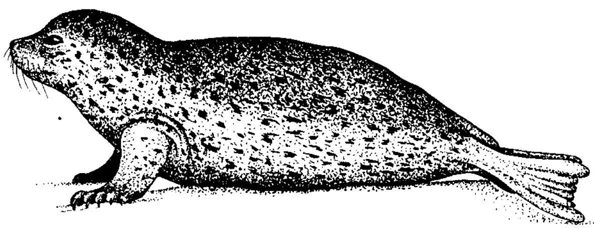


Cottongrass
Tundra

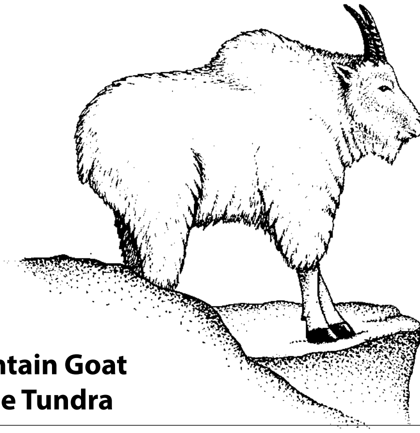
Tundra Adaptation Cards

This mammal has long, dense fur. It has fairly short ears. It turns white in winter.	This mammal has short fur. It has very large ears. It loses a lot of heat through these ears, even on warm days. It stays light brown in color throughout the year.
This bird feeds mainly on grasses and sedges. Its large webbed feet allow it to walk across wet ground and swim on ponds and lakes.	This bird has a specially shaped bill that helps it take seeds out of the cones of spruce trees. It has long narrow toes that can hold onto small branches.
This large insect is covered by soft velvet fur. This fur traps heat made by contractions of the muscles of the insect.	The body of this small insect is covered by a thin coat of fine hairs.
This plant depends on the wind to carry its pollen.	This plant depends upon hummingbirds to carry its pollen.

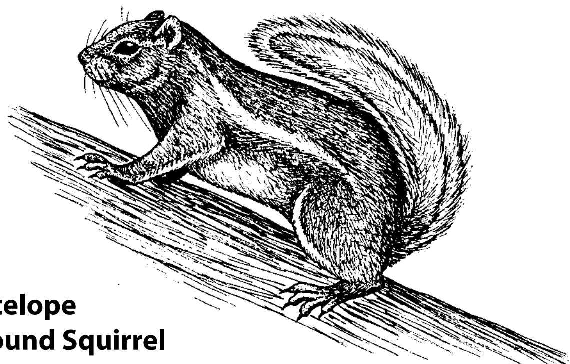
Tundra Adaptation Cards



Harbor Seal
Ocean

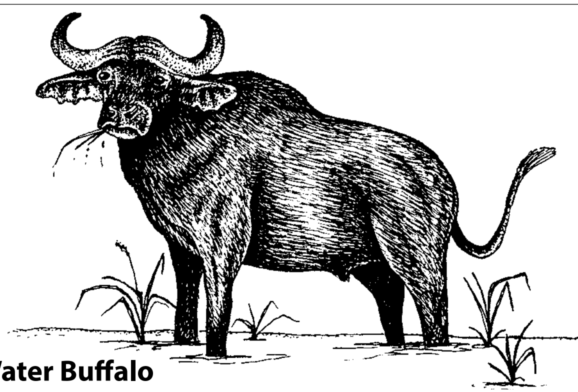


Mountain Goat
Alpine Tundra

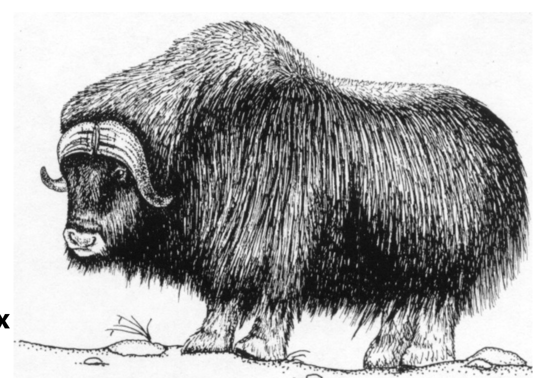


Antelope
Ground Squirrel
Desert

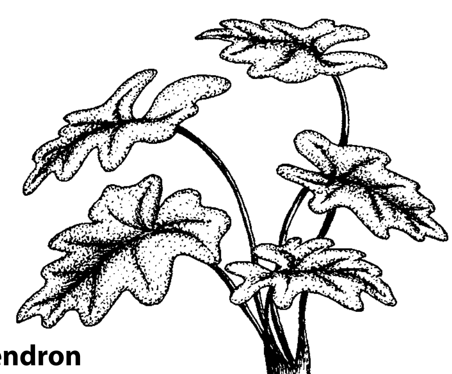
Arctic Ground
Squirrel
Tundra



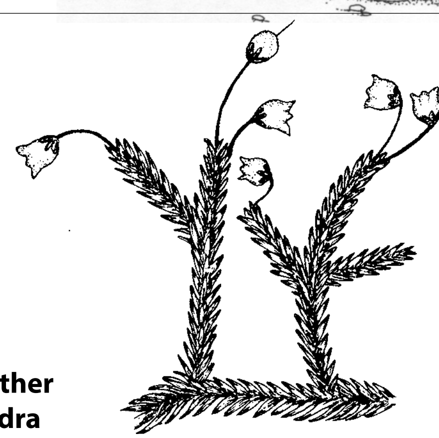
Water Buffalo
Tropical Grasslands



Muskox
Tundra



Philodendron
Tropical Forest



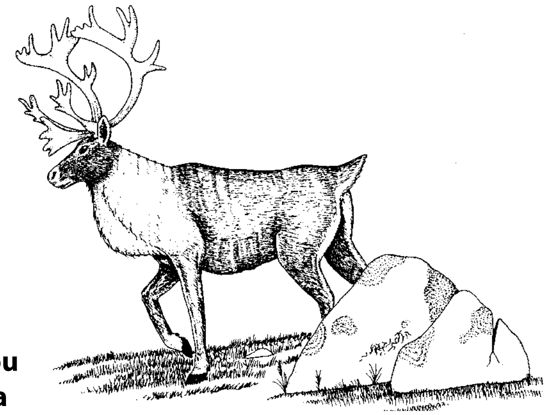
Heather
Tundra

Tundra Adaptation Cards

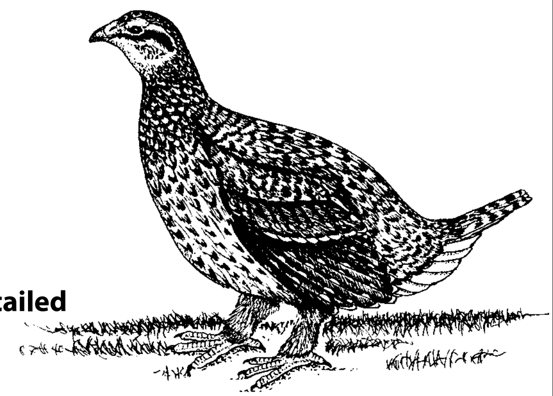
This mammal has long, white fur. It has sharp hooves that are soft in the center. These help it get firm footholds on steep slopes and cliffs.	This mammal has a thick layer of fat, which keeps it warm even at very cold temperatures. Its body is long and round. It has no outer ears. Its fore and hind limbs are short and flattened. It cannot move quickly on land.
This 8- to 13-inch long (20- to 32.5- centimeter) mammal has thick fur. It may weigh 35 ounces (1000 grams). In winter, it has a thick layer of fat underneath its fur coat. It can hibernate for several months. During hibernation, it lives off the energy and water in its stored fat, so it doesn't need to eat or drink. It digs underground burrows.	This 6-inch (15 centimeter) long mammal has short fur and a fairly long tail. It weighs about 3.15 ounces (90 grams). It must eat food throughout the year, but it can survive for weeks without drinking any water. It can be active at temperatures up to 107° F (41° C) without getting too hot. It digs underground burrows.
The long, soft fur of this animal is sometimes 24 inches (61 centimeter) long. This long fur nearly hides the short legs, short tail, and short ears of this large animal. This animal has hooves and large horns.	This animal has short hair and a long tail. It is a large animal with wide hooves. It has large horns on its head.
This plant grows just a few inches tall. Its small, white flowers are shaped like bells. This shape helps them trap the sun's heat and shelters their seed-making parts from wind. Its leaves are small and thick. The leaves are covered with a waxy coating that prevents them from drying in the wind.	This plant grows quite tall. Its large leaves point downward and have small, narrow tips. This shape helps water run off the leaf.

Tundra Adaptation Cards

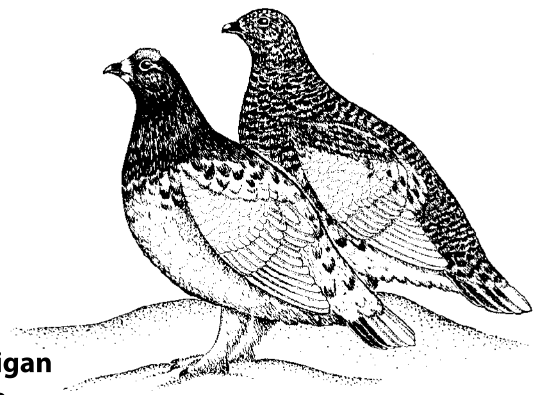
Deer
Forest



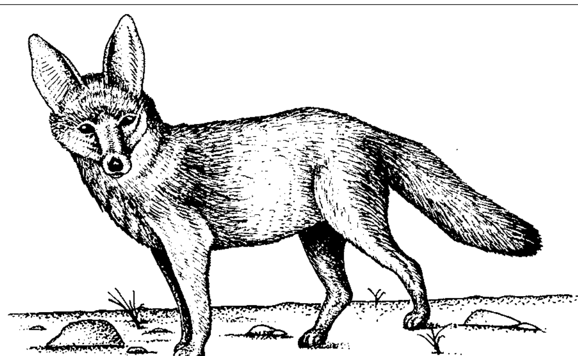
Caribou
Tundra



Sharp-tailed Grouse
Prairie

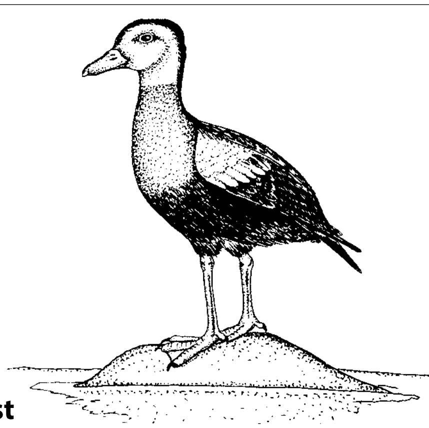


Ptarmigan
Tundra

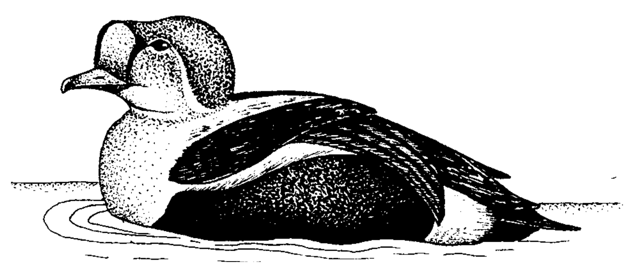


Kit Fox
Desert

Arctic Fox
Tundra



Tree Duck
Tropical Forest

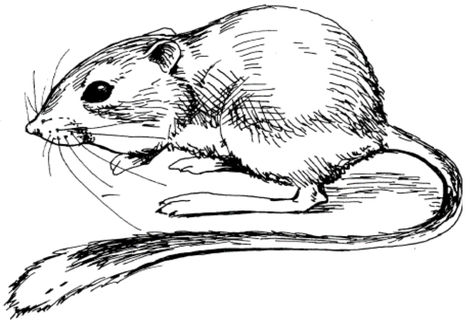


King Eider
Tundra

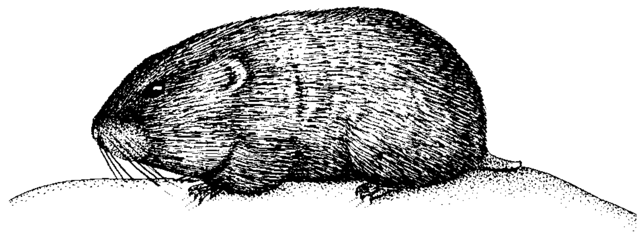
Tundra Adaptation Cards

This mammal has large hooves that help support its weight on wet, soggy ground and crusty snow. It has a thick outer coat of hollow guard hairs. It can use its large hooves as shovels to paw through snow to uncover plants to eat.	This mammal has small hooves and long muscular legs. These traits allow it to run quickly, make sharp turns, and leap over obstacles.
This bird has feathers on its feet and legs. These feathers keep its feet warm and act like a pair of snowshoes in winter. This bird turns white in winter.	This bird's feet are bare. It cannot walk on top of snow unless the snow is very crusted. This bird stays the same color throughout the year.
This small animal has long, warm fur. It turns white in winter. It has short ears. It weighs 7 to 15 pounds (3.18-6.18 kilograms).	This small animal has short fur. It is light brown all year round. It has large ears. It weighs 3 to 6 pounds (1.36-2.7 kilograms).
This bird has a thick layer of soft feathers called "down." The down traps air and allows this bird to stay warm even in icy cold water.	This bird has long legs and large webbed feet with claws for perching on tree branches.

Tundra Adaptation Cards



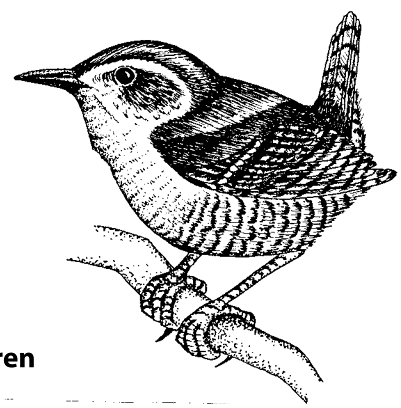
Kangaroo Rat
Desert



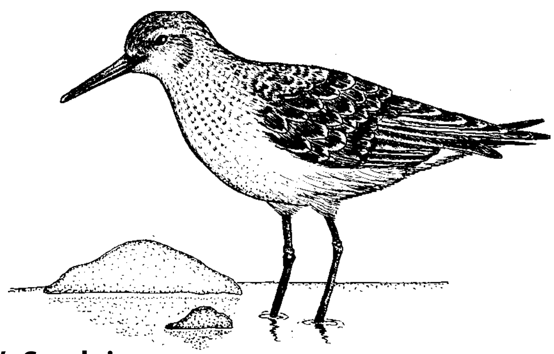
Collared Lemming
Tundra

Great Horned Owl
Forest

Snowy Owl
Tundra



Winter Wren
Forest



Baird's Sandpiper
Tundra

Evening Primrose
Desert

Arctic Poppy
Tundra

Tundra Adaptation Cards

This small mammal has thick fur. It has a short tail, small ears, and short legs. Each winter this mammal grows large claws on its front toes. These claws help it dig tunnels through snow. It turns white in winter.	This small mammal has short fur. It has long ears, a long tail, and long legs. It stays a light tan color year-round. It stays underground during the day and is active at night.
This large white bird feeds on small mammals. It nests on the ground.	This large brown bird feeds on small mammals. It uses nests in trees that hawks and other birds no longer use.
This small bird has long wings and a small body. It is able to fly thousands of miles each year. It eats insects.	This small bird has short wings. It flies well, but only for short distances. It feeds on insects.
This plant has large flowers that turn so they always face the sun. The yellow petals reflect light toward the center of the flower. This helps warm the parts of the flower that form its seeds.	This plant has white flowers that bloom only at night.

Blubber Mitts
1 EXTENSION

Section 3
TUNDRA ACTIVITIES

Grade level: K - 5

NGSS: 3-LS3-2., 4-LS1-1

Subject: Science

Skills: Comparing, analyzing, observing, describing

Duration: 30 minutes

Group size: Small teams

Setting: Indoors

Vocabulary: Blubber, insulation

Objective:
Students will experience the insulating properties of fat that protects some tundra animals from the cold arctic winter.

Materials:
2-6 ice cube trays, 2-6 buckets (*enough to be shared among your class without crowding*), 1-3 gallons of cold water, 1 or 2 containers of soft vegetable shortening, 2-6 one-gallon plastic bags, 2-6 pairs of rubber gloves, masking tape.

Background:
See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:
DAY IN ADVANCE, fill the ice cube trays with water and freeze *overnight*.

Make your own insulated mitts by spooning a pound of vegetable shortening into several 1-gallon plastic bags.

BEFORE CLASS, fill the buckets about *half full* with ice water.

1. *IN CLASS,* divide the class into as many teams as you have buckets. Let students test the insulating properties of each mitt by immersing one bare hand and one protected hand in the ice water.

2. Seal the bag of shortening around a student's hand with masking tape.

3. The student dips both a bare hand and a gloved hand into a bucket of ice water and then describes the differences in feeling between the gloved and ungloved hands.

4. Other students do the same, either with the shortening-filled mitt or with a rubber glove and a bare hand. Ask them to describe the difference in feeling between the gloved and the ungloved hands.

5. Lead a discussion about how tundra animals are insulated. You may want to ask students to write or illustrate their reactions. What if they had an extra fat layer instead of snow pants or a jacket?

VARIATION:

If you have access to a fur pelt piece, fold that into a gallon plastic bag. Seal that onto a student's hand. Students dip their fur covered hand into the ice water and describe how that feels. Compare it to blubber mitt. What if an animal had both fur and blubber?

Evaluation:

Students will select an arctic mammal and explain why it does not get cold.

EXTENSIONS:

1. Compare the winter adaptations of animals. Students pick two animals, one from the tundra and one from another ecosystem. Describe each animal. Tell why the tundra animal can survive the harsh winters.

2. Tundra adaptation lineup. From a series of pictures of tundra, arctic, temperate, and tropical animals, students pick the ones that have blubber or similar adaptations to keep them warm in winter. They explain why insulation is an important adaptation.

Credits:

Adapted from Barbara Molyneaux Wild's, "Blubber Mitts" in *Arctic Explorations: A Teacher's Guide to Arctic Ecology Studies,* The Imaginarium Science Discovery Center, Anchorage, AK, 1996. Extensions contributed by Jeanne L. Williams, Kingikmiut School, Wales, Alaska.

Curriculum Connections:

(See appendix for full citations)

Books:

Scholastic's The Magic School Bus in the Arctic: A Book About Heat (Cole)

One Small Square: Arctic Tundra (Silver)

Secret Language of Snow (Williams)

Teacher Resources:

(See appendix)

Caribou Migration Game
2 AGE-VARIATIONS

Section 3
TUNDRA ACTIVITIES

Grade Level: 4 - 6 & 7 - 10

State Standards: SL.4.1 ,SL.5.1

NGSS: MS-LS2-1.,MS-LS2-4. HS-LS2-8.HS-LS2-1.HS-LS4-4
Subject: Science, geography, art
Skills: Cooperation, reading, researching, drawing, brainstorming, speaking
Duration: Several sessions
Group size: Whole class or small groups
Setting: Indoors or outside
Vocabulary: Calf, calving ground, domestic, herd, home range, migration, mortality rate, predators, rut, tundra, wild

Objective:
Students will describe the process of caribou migration as an adaptation for survival in their environment.

Teaching Strategy:
Students study caribou migration, create a mural depicting the challenges caribou face during migration, and play a "Caribou Migration Game." Older students create a caribou migration game and mural for younger students.

Complementary Activities:
"Tundra Adaptations" and *"Design Your Tundra Animal"* in this section. *"Tundra Writing Adventure"* in Section 4, and *"Harvesting Wildlife"* in Section 5. Also *"Graphic Populations"* in *Alaska's Wildlife for the Future.*

Materials:
Alaska or regional maps, information on caribou in general and on a specific Alaska caribou herd, mural paper, art supplies.

Background:
See *INSIGHTS Section 3: Tundra Adaptations: "Migration."* See also *Alaska's Wildlife for the Future, INSIGHTS, Populations.*

Procedure:
PART ONE – Gr. 7-12

1. Introduce or review the concept of migration, using caribou as the example. Include the following information:
- Caribou travel across great distances throughout the year to find food, avoid insects and predators, and to **rut** and **calve** in favored areas.
- This travel, called "**migration**," generally occurs in the same area from year to year.
- Caribou gather in large groups called **herds.**
- In Alaska, "caribou" are **wild** and "reindeer" are **domestic**. They are actually the same animal.
- During the yearly migrations, some caribou die. The ratio of deaths to live animals in a herd is the **mortality rate**.
- Calf **births** and **survival rates** are important factors in determining the population of a herd.

2. Look at a map of Alaska and brainstorm challenges that caribou may encounter during migration.

3. In class or as homework, students research general information on caribou and migration.

4. As a class, select one Alaska caribou herd to research in depth. Include population trends in student research.

5. Divide students into four groups, each to study and then illustrate spring, summer, fall, and winter challenges of the chosen herd.

6. Students create a large mural illustrating challenges, caribou behavior, and caribou life history during their assigned season.

7. Ask the students to predict what their chosen herd's population will do in the coming year.

PART TWO – Gr. 7-12

1. Using the mural they designed, students create a room-sized board game for younger students. They develop clear directions. *A sample of game board squares is provided below.*

Some considerations:

- The game should demonstrate to younger students that caribou, like may other tundra wildlife, migrate and encounter challenges on their yearly journeys.
- The game should start and stop in a circle, illustrating the migration cycle and importance of the **calving grounds**.
- Students may chose to create caribou mortality cards that the younger students hand in during the game when a caribou in their group dies. In this way, younger students may participate in the entire activity.

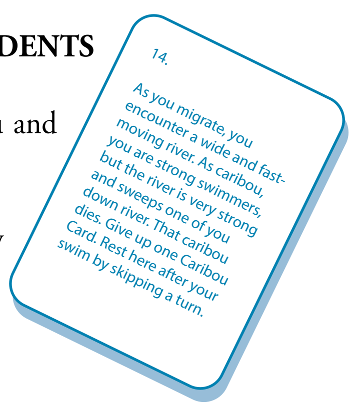
2. Students test their Caribou Migration Game and make modifications.

3. Students then present the activity and mural to a younger class. *(If this cannot be arranged, students canpresent the activity and game to a teacher who will use the activity with a younger class.)*

VARIATION FOR YOUNGER STUDENTS (Gr. 4-6)

1. Introduce your students to caribou and caribou migration.

2. Have students look at maps that show the range of a local caribou herd. Point out river crossings, mountain passes, and other land challenges. Brainstorm what challenges caribou face as they travel throughout the seasons and their range.



3. Students create a mural depicting a one-year migration cycle.

4. Set up a game path around the room on the floor. Use the sample game cards *(following pages),* modifying them for a local caribou herd. Each student gets five "Caribou Cards" (see page 135).

5. To play the game, students move through the year, reading their steps aloud. If something is missing from their mural, have students add to the mural at a later date.

Evaluation:

1. Students define migration.
2. Students explain the importance of migration for caribou survival.
3. Students identify several specific examples of challenges that caribou face during migration.
4. Students explain the connection between caribou behavior and the seasons.

Curriculum Connections:

(See appendix for full citations)

Books:

Caribou Girl (Murphy)

A Caribou Journey (Miller)

Home at Last: a Song of Migration (Sayre)

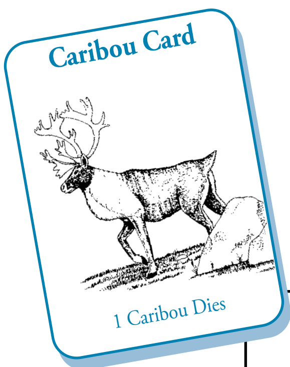
Moose, Caribou and Musk Ox (Alaska Geographic Society)

Websites:
Alaska Department of Fish and Game <www.adfg.alaska.gov> for information on Alaska's caribou herds, video of biologists at work, and *Alaska Wildlife Notebook Series, "Caribou" fact sheet* on line.

Arctic Animals Home <tqjunior.advanced.org> (Thinkquest)

Caribou Q&A's, maps <arctic.fws.gov> (Arctic National Wildlife Refuge)

Teacher Resources:
(See appendix)



Sample Caribou Migration Game Board

First group moves ahead one space, second group two spaces, etc. Students then follow directions on each card. If there are no directions, students move ahead one space at each turn.

1.

Starting line / Finish line.

Calving grounds in late spring (May and June)

2.

Calves are born! By the end of the day, you can outrun people and even wolves. **Cows** (female caribou) and calves stick together. At this time females have antlers, and males do not.

3.

Food is plentiful, you gain weight, doubling your size in only two weeks. Move ahead four spaces.

4.

Wolves, bears and eagles are **scarce.** Move ahead five spaces.

5.

Food is plentiful, eat and move ahead.

6.

Wolves, bears and eagles are **scarce**. Stay in the area one turn and graze on food.

7.

Wolves, bears and eagles are **scarce**. Stay in the area one turn and graze on food.

8.

Wolves, bears, and eagles are **scarce**. Move ahead.

9.

It's early summer now; mosquitoes are out. Begin migration toward summer range by moving two steps forward.

10.

Migration continues. Move ahead.

11.

Food is available as you migrate. Move ahead two spaces.

12.

Mosquitoes are really thick. Each of you loses a lot of blood and is weak.
Skip one turn.

13.

As you migrate, you encounter a river. As caribou, you are strong swimmers. Cross the river
without difficulty. Move ahead two spaces.

14.

As you migrate, you encounter a wide and fast-moving river. As caribou, you are strong swimmers, but the river is very strong and sweeps one of you down river. That caribou dies. Give up one Caribou Card. Rest here after your swim by skipping a turn.

15.

Mosquitoes are really thick. You run wildly to escape the bugs. One of you loses too much blood and energy, falls, and is then killed by a brown bear. Give up one Caribou Card. Move ahead one space.

16.

As you migrate closer to the ocean, you encounter wolves. The wolf pack chases your group and kills one of you. Give up a caribou card. Move ahead 2 spaces.

17.

It has been three weeks since the birth of the calves. You have traveled far and are now in the summer range, in a very large group. Move forward one space, then another. Caribou are always on the move in search of food. The bugs are still thick.

18.

Female caribou begin to lose their antlers. They protect their calves by
keeping close to other caribou.
Caribou are safer in a group than alone. Move ahead.

19.

The bugs are really thick and bite you often. In an effort to escape the bugs, the herd runs wildly across the tun-dra. One of you breaks a leg and dies. Give up one Caribou Card.

20.

You find a patch of snow to rest on. It is cooler, and there are fewer bugs. Rest here two turns. Then move ahead one.

21.

The herd is very large now, and all of you eat as you migrate. The herd must keep mov-ing to find food. Move forward.

22.

As you migrate closer to the ocean, you encoun-ter wolves. The wolf pack chases your group, but you get away. One caribou calf breaks a leg and is killed by a golden eagle. Give up one Caribou Card. Move ahead.

23.

It is July, and the bugs are biting you all the time. Stand in a lake to cool off and avoid the bugs. Rest for one turn.

24.

It is late August, and antlers on male caribou are
changing. The velvet is coming off. Your antlers are itchy all the time. You scrape your antlers on the ground and on bushes. Move
forward.

25.

Fall has begun. It is early September, and males "go into rut," showing their strength. During the rut, one of you is injured and dies. Give up one Caribou Card. Move ahead.

26.

Fall has begun, it is early September, and males "go into rut," showing their strength. One of the male caribou wins a fight. Move ahead.

27.

Fall has begun, it is early September, and males "go into rut," showing their strength. After a long fight, one male caribou is exhausted and killed by a bear. Give up a caribou card. Move ahead.

28.

It is mating time; cari-
bou mate. Move for-
ward two spaces.

29.

As you migrate, eat lichen and blueberry bushes. Willow leaves are harder to find now. Move ahead.

30.

It is now late October, and the big **bulls** (males) **shed** or drop their ant-
lers. Smaller bulls and fe-
males keep their antlers. Move forward.

31.

You hear a loud, sharp "boom" as a human hunter in search of food kills the caribou next to you. Give up one Caribou Card. Move forward.

32.

The winds blow colder, and the first snowstorm of the winter comes. Fall migration begins. Move forward two spaces.

33.

The rut is over, and males drop their ant-
lers. Smaller bulls and females have antlers to help
themselves protect and to keep food to them-
selves.
Move ahead.

34.

You are now travelling as much as 50 miles a day. Keep eating lichen and berry bushes. Move forward two spaces.

35.

As you travel, your knees make a clicking sound. The wind blows and it is getting colder. Move ahead.

36.

As you migrate, you break up into smaller groups and spread out across the land in search of food. It is harder to find food. One of you dies of starvation. Give up one Caribou Card. Move forward.

37.

As you migrate into places where there is less wind, you must travel over rivers and across lakes. Your hollow hairs help you stay afloat as you swim. Move forward.

38.

There is now snow on the ground, and you must dig for food. You can smell lichen beneath the snow, and you use your shovel-like hooves to dig. Move forward.

39.

In the woods, wolves are dangerous **predators**. You find a large frozen river with muskrat pushups. Pushups are mounds of green grasses that muskrats push up though the ice for storage. You dig these up and eat the fresh greens. Move forward.

40.

The snow is deep, but your hooves are wide, like snowshoes, and help you travel through the snow. Move for-ward.

41.

The days are getting lon-ger and warmer. Spring is coming and the cows are pregnant. You begin migrating toward the calving grounds. Move forward two spaces.

42.

Your small group is traveling across a river when one of you falls through the ice and dies. Give up one caribou card. Move ahead.

43.

Your small group trav-els through the forest, migrating toward the same calving grounds where you were born. Move forward.

44.

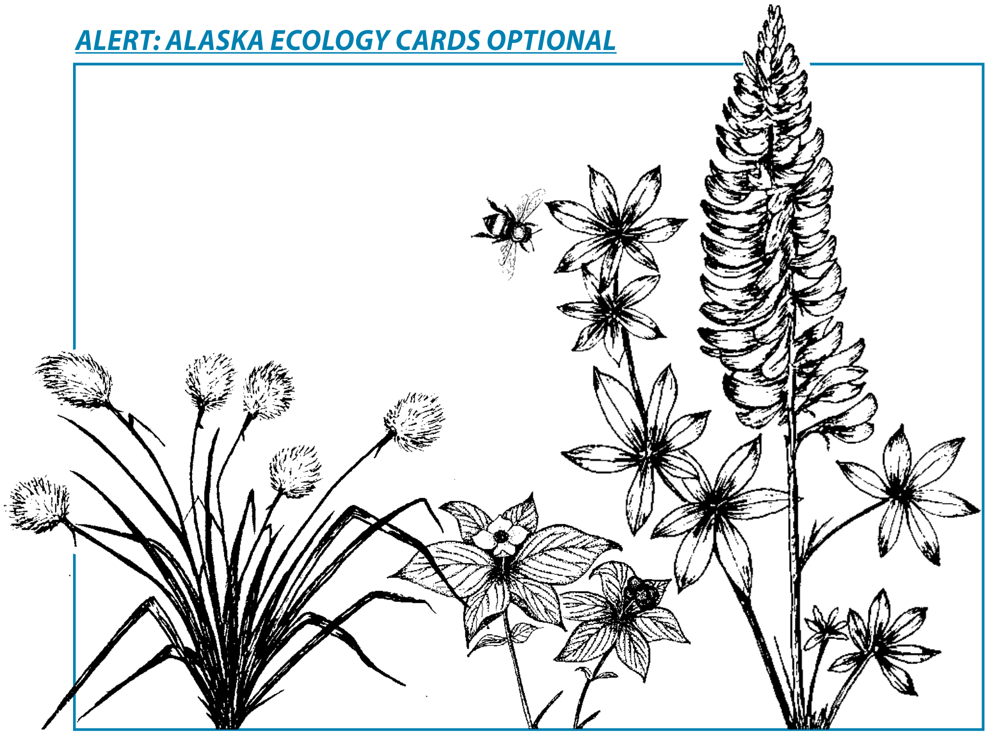
As you migrate, you encounter a fast moving river. As caribou, you are strong swimmers, but the river is very strong and sweeps one of you down river. That caribou dies. Give up one Caribou Card. Move ahead.

45.

You reach the calving grounds! Pregnant cows have calves as the life of your caribou herd continues on, and on, and on.

Plan Your Tundra Plant

ALERT: ALASKA ECOLOGY CARDS OPTIONAL



Section 3
TUNDRA ACTIVITIES

Grade Level: 3 - 8

State Standards: S A-12, S B-1, S B-5, S B-6, AC E-2

Subjects: Science

Skills: Relating, categorizing, designing, synthesizing, developing

Duration: May vary from 30 minutes to several periods

Group Size: Whole class

Setting: Indoors

Vocabulary: Adaptations

Objective:
Students will synthesize information about tundra plant adaptations.

Teaching Strategy:
Students will use information from previous lessons and experiments to design a plant that could survive in a tundra environment.

Prerequisite:
"Flower Flip Book" or *"Tundra Adaptations,"* both in this section.

Complementary Activities:
"Draw Your Tundra Animal" in this section.

Materials:
Information about tundra plants from *INSIGHTS Section 3,* copies of *Tundra Adaptations Fact Sheets, Alaska Ecologoy Cards,* or pictures of tundra plants and plant adaptation descriptions from *Flower Flip Book* activity (in this section); drawing paper; pencils or paints.

Background:
See *INSIGHTS Section 3, Life Forms and their Tundra Adaptations.*

Procedure:
1. Students will identify the environmental components of tundra that affect plants. *These include cold, strong winds, low temperatures, and short growing seasons.*

2. Review tundra plant adaptations with the students.
Size – Tundra plants are generally small and /or form low, flat mats to reduce wind abrasion and to benefit from the warmer temperatures found within inches of the ground.
Color – The dark colors of many tundra plants help to absorb heat from the sun.
Heliotropism – Tundra plants that track the movement of the sun have light-colored petals that reflect the heat of the sun toward the center of the flower and aid in seed production.
Surface hairs – Hairs on stems and leaves block wind and trap warm air.
Waxy coatings – Waxy coatings help resist wind and cold, reduce water loss, and reduce evaporative cooling by the

wind.

Antifreeze – Plant antifreeze allows photosynthesis and production of sugars to continue at temperatures below the freezing point of water.

Retention of dead leaves – Dead leaves that are not shed by tundra plants serve to insulate new plant growth from wind and cold.

Growth rate – Tundra plants tend to grow faster to take advantage of the shorter growing season.

Food storage – Storage of sugars in underground roots allows many tundra plants to begin new growth even before all the snow melts in spring.

Reproductive methods – The use of rootstocks or runners in place of or in addition to seeds saves energy and insures reproduction under harsh conditions.

3. Students will look at pictures of tundra plants and discuss the variety of adaptive features they employ. If possible, observe plants around the schoolyard.

4. Using information about tundra plant adaptations, students will design a plant that can survive in a tundra environment. The degree of detail and complexity is grade-dependent. Students will draw and label their plants.

Primary students might focus on two or three adaptive components such as size, color, and surface coverings.

Older students could design their plant by identifying adaptations for food production and storage, water and heat retention, reproductive methods, and others.

Evaluation:

Students will write (or dictate) a paragraph, or an oral report, describing the adaptive features plants that will allow them to survive and pros tundra setting.

Credit:

Contributed by Jeanne L. Williams, Kingikmiut School, Wales, Alaska.

Curriculum Connections:

(See appendix for full citations)

Books:

A is for Arctic (Lynch)

Arctic Tundra: Land with No Trees (Fowler)

*Discovering Wild Plants: Alaska, Western Canada, the Northwest (*Schofield)

Field Guide To Alaskan Wildflowers (Pratt)

A Naturalist's Guide to the Arctic (Pielou), 9-12

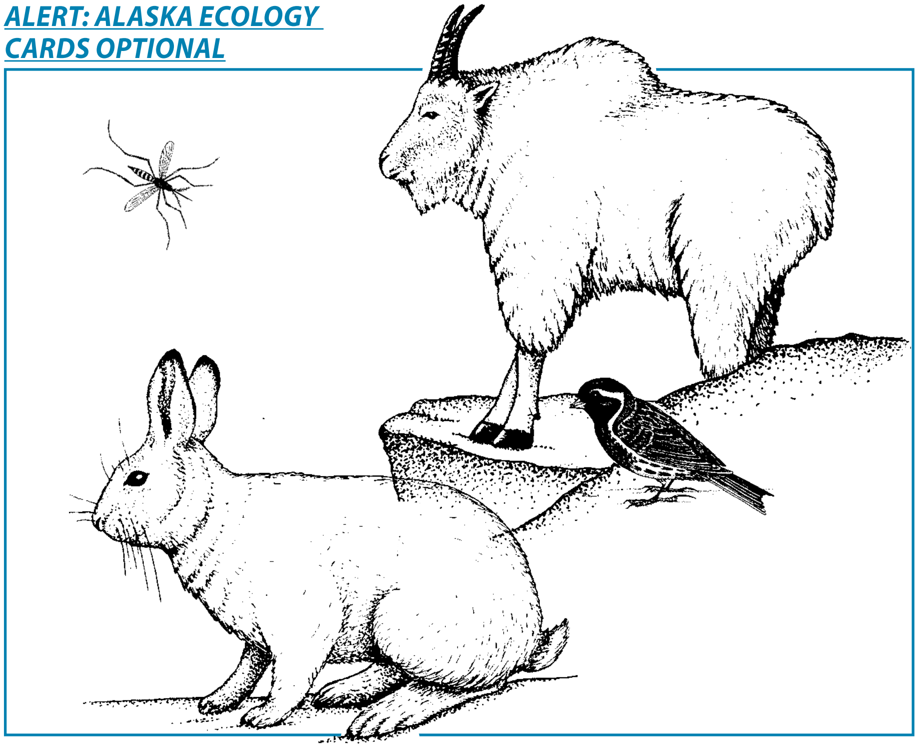
Tundra (Sayre)

Teacher Resources:

(See appendix)

Draw Your Tundra Animal

ALERT: ALASKA ECOLOGY CARDS OPTIONAL



Section 3
TUNDRA ACTIVITIES

Grade Level: 3 - 8

NGSS: 3-LS3-2, 4-LS1-1, 3-5-ETS1-1. 3-5-ETS1-2, MS-LS1-4., MS-LS4-4 HS-LS4-4.

Subjects: Science

Skills: Relating, categorizing, designing, synthesizing, developing

Duration: may vary from 30 minutes to several periods

Group Size: whole class

Setting: Indoors

Objective:
Students will synthesize information about tundra animal adaptations.

Teaching Strategy:
Students will use information from previous lessons and experiments to design an animal that could survive in a tundra environment.

Prerequisite:
"Flower Flip Book" or *"Tundra Adaptations,"* both in this section.

Complementary Activities:
"Plan Your Tundra Plant" and *"Caribou Migration"* in this section.

Materials:
Information about tundra animals from *INSIGHTS Section 3,* copies of *Tundra Adaptations Fact Sheets,* pictures of tundra animals, *Alaska Ecology Cards*, and plant adaptation descriptions from *"Flower Flip Book"* activity *(in this section);* drawing paper; pencils or paints.

Background:
See INSIGHTS *Section 3, Life Forms and their Tundra Adaptations.*

Procedure:
1. Students will identify the environmental components of tundra that affect animals. *These include cold, strong winds, low temperatures, extreme daylight fluctuations, and severe winters.*

2. Review tundra animal adaptations with the students. Use the *Tundra Adaptations Fact Sheets* to discuss the following:

- Food acquisition and storage
- Migration
- Hibernation
- Shelters
- Body shape
- Fur, feathers, fuzz, and movement
- Color
- Antifreeze
- Growth and reproduction

3. Students will look at pictures of tundra animals and discuss the physical features and adaptive strategies these

Utqiagvik animals employ to enable them to live in a tundra environment.

4. Using information about tundra animal adaptations, students will design an animal that can survive in a tundra environment. The degree of detail and complexity is grade-dependent. Students will draw and label their animals.

Primary students might focus on two or three adaptive components such as body shape, color, and outer coverings. **Older students** could focus their designs on physical features but also include adaptive strategies that address food acquisition and storage, winter behavior patterns, types of shelters, and reproductive strategies.

Evaluation:
Students will write (or dictate) a paragraph, or prepare an oral report, describing the adaptive features of their animal that will allow it to survive and prosper in a tundra setting.

Credit:
Contributed by Jeanne L. Williams, Kingikmiut School, Wales, Alaska.

Curriculum Connections:
(See appendix for full citations)

Books:
A is for Arctic (Lynch)

Above the Treeline (Cooper)

Alaska's Mammals (Smith)

Alaska Wildlife Notebook Series (ADF&G)

Arctic Animals (Kalman)

Mammals of Alaska (Alaska Geographic Society)

A Naturalist's Guide to the Arctic (Peilou), 9-12

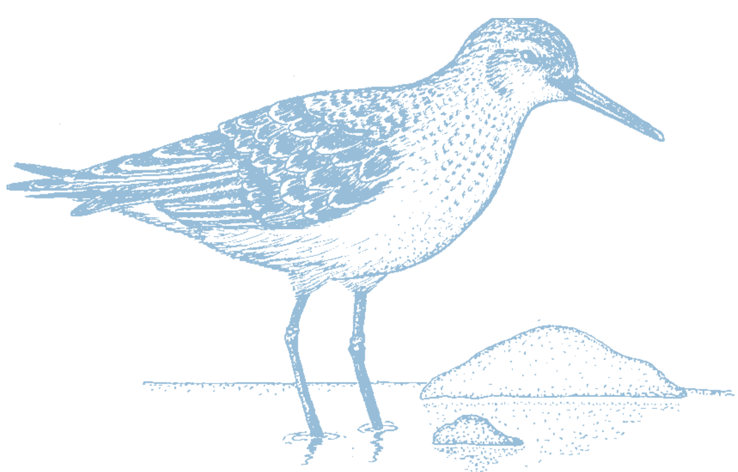
Tundra Discoveries (Wadsworth)

Websites:
Alaska Wildlife Notebook Series on line <www.state.ak.us/adfg> (ADF&G)

Arctic wildlife <arctic.fws.gov> (Arctic National Wildlife Refuge)

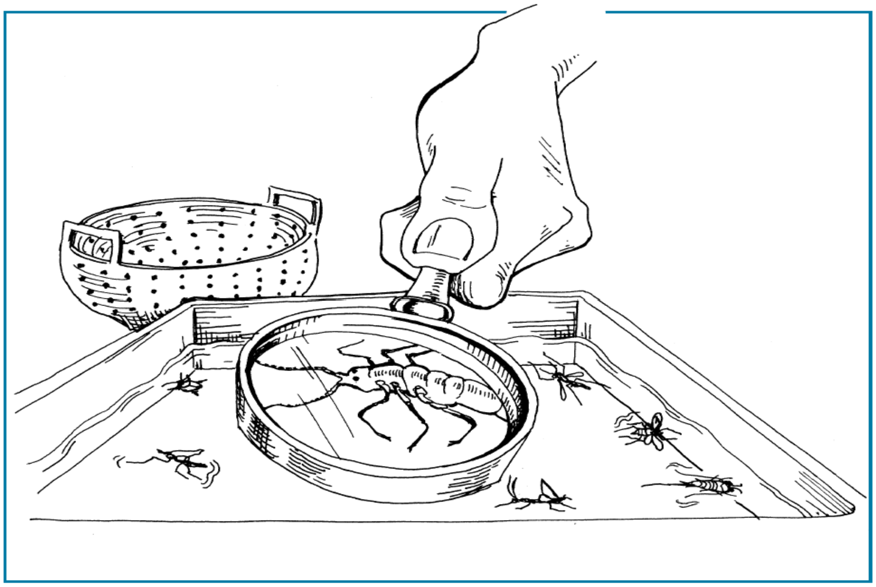
Audubon On Line Field Guides <www.enature.com>

Teacher Resources:
(See appendix)



Life in the Tundra Soil

2 EXTENSIONS ***ALERT: ALASKA ECOLOGY CARDS REQUIRED***



Section 4
TUNDRA ACTIVITIES

Grade Level: 4 - 12

NGSS: 5-LS2-1.

Subjects: Science, math

Skills: Estimating, measuring

Duration: 2 class sessions, separated by 24 hours

Group Size: Small, or whole class

Setting: Indoors

Vocabulary: Dormant, invertebrates, larval stage, pupae, springtails

Objective:

Given a sample of tundra soil, students will estimate and measure the invertebrate organisms in it.

Teaching Strategy:

Students find invertebrates in a tundra soil sample and count their numbers.

Materials:

Perforated bowl or colander, tray or baking pan filled with water, incandescent light, hand lenses or insect boxes, sample of tundra soil collected in the fall or spring and placed in a glass jar (*if you don't live near tundra, ask someone to collect a soil sample from a nearby mountain*).

Copies of the *Alaska Ecology Cards* for the following: roundworms, rotifers, segmented worms, mites, springtails, rove beetles, craneflies, midges, black flies, fungus gnats, ichneumons, blowflies, and bumblebees.

Optional: Insect field guides *(see Curriculum Connections, following)*.

Background:

See INSIGHTS *Section 4, Tundra Ecosystems: "Detritivores Reuse and Recycle."*

Procedure:

1. Collect a sample from the top 2 to 5 inches (5-13 centimeters) of tundra soil. Place this in the jar. Ask students to guess how many animals are in the soil sample. Each student has one guess. Write their guesses on the board or on chart paper.

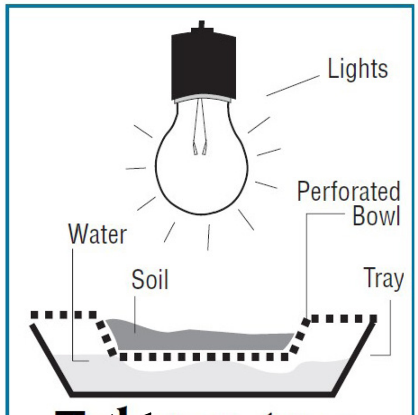
2. Force the invertebrates out of the soil sample by using a "Tulgren tray." A Tulgren tray *(illustration follows)* is made by setting a perforated bowl or colander in a tray or baking pan full of water. Water should not reach the holes of the colander. Empty the soil sample into the colander.

3. Shine a light on the top of the soil. The soil invertebrates will move downward to flee from the warm light. After 24 hours, count the number of organisms that tumble out

into the water or cling to the bottom of the colander.

4. Ask students to observe the creatures closely with hand lenses or magnifying glasses. What invertebrates can they identify, using the *Alaska Ecology Cards* or an insect field guide?

5. Count all the animals present. Compare this amount to the guesses on the board. Discuss the number of invertebrate animals scientists have found in samples of tundra soil.



Tulgren tray

Evaluation:

1. Ask students to explain why the Tulgren tray model is successful. Would it work if they didn't shine the light overhead? What if they moved the light closer to or farther from the dirt sample? What does the light in this model represent? What season is being simulated?

2. Ask the students the following questions:
• Would you expect to find more invertebrates in forest soil or tundra soil? Why?
• Why are invertebrates important in tundra soil?
• What is their role in the tundra ecosystem?

Students write answers to their questions and discuss their papers with the class.

EXTENSIONS:

A. **Apply knowledge to population estimates.** Based on experience in this activity, students estimate the number of invertebrates in one tablespoon of tundra soil, in one cup of tundra soil. Older students can estimate numbers for larger areas.

B. **Create an illustrated graph.** Students draw pictures of the different invertebrates found in the soil. Students cut out the pictures and use them as labels on a graph. The graph will show the number of each type of organism.

Curriculum Connections:

(See appendix for full citations)

Books:

National Audubon Society First Field Guide, Insects (Wilsdon)

A Naturalist's Guide to the Arctic (Pielou), 9-12

One Small Square: Arctic Tundra (Silver)

Peterson's Field Guide to Insects (Borror)

Peterson First Guides: Insects (Leahy) (for younger students)

Websites:

Audubon On Line Field Guides website <www.enature.com>

Teacher Resources:

(See appendix)

In tundra that has severely cold summers, most insects crawl rather than fly, because the energy cost of flying is too great!

Di's Story

1EXTENSION ***ALERT: ALASKA ECOLOGY CARDS OPTIONAL***

Section 4
TUNDRA ACTIVITIES

Grade Level: K - 6
State Standards: RI.K.1,RI.K.3 RI.1.1,RI.2.1,RI.2.3,RL.3.1,RI.3.3 RL.4.1,RI.4.3,RI.5.1,RI.5.3,W.K.3 W.1.3,W.2.3
NGSS: K-LS1-1.,K-ESS2-2., K-ESS3-, 1-LS1-2.,2-LS4-1,3-ESS2-2.,4-LS1-2, MS-LS1-4., MS-LS2-1,MS-LS2-2.

Subjects: Language arts, science, art
Skills: Listening, visualization, art, identification

Duration: 3-5 classes

Group Size: Individual
Setting: Indoors

Vocabulary: Adaptations, habitat, hibernate, insulation, lemming, predator, permafrost, tundra

Objective:
Students will describe the characteristics of a tundra ecosystem and draw its elements.

Teaching Strategy:
Synthesizing what they hear in a story about lowland tundra animals, students draw pictures to illustrate the story and make a book of their illustrations.

Complementary Activity:
"Getting to Know Tundra Wildlife – Tundra Writing Adventure" in this section. Also *"Snow Blanket"* in *Section 1, Elements that Create Tundra.*

Materials:
Depending on grade, one to several copies of "The Story of *Dicrostonyx torquatus*" *(following pages)*, pencils or pens, drawing paper, yarn, hole punch or staples for binding student books.
OPTIONAL: *Alaska Ecology Cards* or other pictures of tundra animals, photocopies of the class book.

Background:
See *INSIGHTS Section 4, Ecosystems;* also *INSIGHTS Section 1: "Snow Blanket"* and *"Permafrost"; Section 2: "Permafrost";* and *Section 3, Adaptations.*

Procedure:
1. Explain that you have a story about some Alaska animals. Because it doesn't have any pictures, students will need to use their imaginations to picture the places and animals in the story. Later, they will help to illustrate the story.

2. The story is about a collared lemming scientists have named *Dicrostonyx torquatus*. (Di-KROS-te-nix Tor KWA-tus). *Scientists give all animals two-part names derived from Latin and Greek. Scientists use these names so that people all over the world, no matter what language they speak, can identify each animal.*

3. Ask one student to read the dictionary or field guide definition of a **lemming**. Show the class pictures of lemmings and their habitats. *(Lemming mounts are available in the "Tundra Kit," on loan from the Alaska Science Center, Alaska Pacific University – see* Teacher Resources *for Section*

4 in Appendix.) Also show pictures of the other animals in the story (use *Alaska Ecology Cards).*

4. Explain that this story is divided into four chapters, which correspond to the four seasons.

Chapter 1. WINTER. Di's story begins in winter when she is born in a grass nest beneath the snow. Explain that lemmings do not **hibernate** in the winter. What **adaptations** must they make to survive in the winter? Ask the class why they think lemmings live beneath the snow. Students usually easily guess the wind as an answer, but they may have trouble understanding the **insulation** value of snow *(*see INSIGHTS *Section 1, "Snow Blanket").*

Chapter 2. SPRING. What happens during breakup as everything melts? How will this affect the lemming's tunnels and nests? Encourage students to think of the surprises above ground – new plants, the return of **tundra** animals, and **predators**.

Chapter 3. SUMMER. The tundra continues changing. Notice the references to the small size of the plants and the permanently frozen soil. Ask students to define **permafrost** *(*see INSIGHTS *Sections 1* and *2).* Di also finds her partner, her mate, in the summer. Together, they build their nest.

Chapter 4. FALL. Snow arrives in the fall, and Di welcomes its return and the warmth of the snow tunnels and nests. She encounters the weasel – a danger she recalls from last winter. As winter progresses, the story leaves Di raising her own litter of young.

5. Read the story aloud to the class. You may wish to give each student a copy of the story and take turns reading aloud.

6. Pause at the end of each chapter and discuss how the season affected Di – for example, where she lived (her **habitat**) and the dangers she encountered. What are the signs of the seasons? List the clues or settings on four pieces of butcher paper.

7. Divide the class into four cooperative learning groups. Assign each group a chapter (*a season*).

8. Give the group a copy of the chapter, writing and art supplies, and the appropriate piece of butcher paper on which you have listed the setting. Depending on their grade levels, students may rewrite the story in their own words or illustrate the setting and events.

9. Assemble the four chapters, and bind them together as a class book.

VARIATION FOR YOUNGER STUDENTS:
Students make a mural showing the four seasons described in the story and the various plants and animals present in each of the seasons. Divide the responsibilities between work groups. For example, one group may draw the spring background, while another group cuts out spring animals to paste on the mural. Use the mural to discuss the tundra environment and its seasons.

Evaluation:

1. Students list at least three characteristics of tundra ecosystems.

2. Students work individually or in teams of 2 to 4 to write a story similar to Di's story using their own imaginary animal.

EXTENSION:

Create a play. Using Di's story as a base, students create a play and perform for the community or another class. Different students play Di in the different seasons of her life.

Curriculum Connections:

(See appendix for full citations)

Books:

A is for Arctic (Lynch)

Above the Treeline (Cooper)

One Day in the Alpine Tundra (George)

Tundra (Kaplan)

What is a Lemming? (Souza)

Teacher Resources:

(See appendix)

The Story of *Dicrostonyx Torquatus*, The Collared Lemming

by Susan E. Quinlan

CHAPTER 1
WINTER – A WORLD TO DISCOVER

Dicrostonyx torquatus, or Di for short, was a collared lemming. She lived on the tundra in northwestern Alaska. On the day she was born, the temperature was 30 degrees below zero, and the tundra was frozen under a blanket of snow. Icy winds howled through the dark winter air.

Tiny Di and her litter mates (brothers and sisters) were born with their eyes still closed and with no hair. They would have frozen in the cold air. Instead, they were warm inside a nest of grasses that their parents had built beneath the snow.

The tiny lemmings slept and drank milk from their mother. Slowly, they grew soft fur and opened their eyes.

One day Dicrostonyx was awakened by a pinch on the back of her neck. She squirmed and twisted only to find that she was hanging from her mother's mouth. A terrible smell filled the air of the nest. That horrible smell and her mother's strange actions made Di feel very afraid. She hung limply as her mother carried her out of the warm nest.

Her mother then ran down a long, dark tunnel. Di's back end and feet felt icy cold when they brushed against the sides of the tunnel. Di sensed that her mother was alarmed.

Her mother hurried through one tunnel, then another. Finally she dropped Di inside a new grassy nest and then left. Di fluffed her fur out and curled into a ball to keep warm.

Di's mother returned in a few minutes. She dropped another litter mate she was carrying, then stopped. She listened carefully and sniffed the air. Di did the same. She heard the wind overhead. Wssshhhhhh, Wshhhhhhhhh, it whistled. She smelled the grasses of the new nest, her parents, and her litter mates.

And, very faintly, she smelled that terrible odor that she had noticed in the old nest. Di now knew that the awful smell meant danger. For now, though, she was safe in the new nest with her parents.

Di and her litter mates grew larger over the next few days. Soon there was not enough milk to feed all the growing young. Di felt hungry and the nest felt too crowded. So she left the nest. It was colder outside of the nest, but Di stayed warm because by now she had grown long fur. She slowly walked down the snow tunnel away from the nest.

She looked at, listened to, and smelled all the new things she found. Soon she smelled something that made her remember she was hungry. She dug through the snow without thinking. Two shovel-like claws on her front paws helped Di scrape and dig through the hard snow. She found a small willow plant. Di filled her stomach with the twigs and buds of this plant. Then she began exploring again.

Di scurried from one tunnel to another for the next several weeks. She slept in nests she found along the way. She ate whatever smelled good. Di could not find very much to eat, so she had to move farther and farther away from the place where she was born.

One day she found a tunnel that ended above the snow. Di cautiously peeked out into the open air.

Ice crystals blown by a strong wind blasted into her face. The wind bit the tip of her nose, and her breath turned to white fog. Di was still curious. She poked her head out further and saw a small hill. The hill was only two feet tall but to Di it looked very large. She scampered up it to find out what was on top.

She found a patch of ground without any snow. The frozen soil was bare and brown. Di saw only a few small plants. The dead leaves and stems of these two-inch-tall plants spread over the ground like mats. Di ate a few buds that she found hidden under these dead leaves. Then she looked around.

Flat, snow-covered ground stretched out as far as she could see. There were no trees or mountains to block the view. The sun was just above the southern horizon. It lit the sky with a reddish light.

Just then Di heard a noise. Crunch, crunch! Di dove back into her snow tunnel. Then she turned around and looked out carefully. She saw six giant beasts moving towards her.

The crusty snow squeaked and snapped beneath their feet as they walked. Their short legs were almost hidden by long, woolly fur. Each one had horns that looped down either side of its shaggy face. They stopped to paw the ground as they moved nearer to Di.

They nibbled at some plants, then stopped to chew. They did not seem to notice the bitter cold and wind. But Di suddenly felt cold. She turned and ran back down her tunnel to a warmer spot beneath a large drift of snow.

Di dug her own tunnels to find food during the next few months. She learned that it was warm beneath soft, deep snow and cold under the crusty snow. She also found many new things. One day she found a beetle that was frozen. Another day she found frozen berries. She ate these. She also nibbled on the frozen buds of willow and gnawed on the stems of grasses.

Di soon learned to recognize the sounds of other animals. She knew the sounds that other lemmings made as they gnawed on twigs. She knew the sound of muskoxen crunching through the snow.

She also learned to recognize the sniffing and pat, pit, pat of a hunting arctic fox. Di knew she must fear this sound. Whenever she heard it, she sat very, very still.

Each day in the snow tunnels was just like the last. Di dug tunnels through the snow. She looked for food and found it. She listened to the sounds around her and always hid when she heard a fox. The arctic tundra provided Di with food, shelter, and places to hide from her predators. She could not have had a better home.

CHAPTER 2
SPRING – CHANGES IN THE AIR

Di often dug tunnels to the surface of the snow just to see the world above the snow. Once when she dug a tunnel to the surface she saw another tunnel in the snow just a few feet away. She saw nothing around except white snow, so she decided to have a closer look at it.

She noticed that the sky was brightly lit out in the open. The wind was still, and the air seemed warmer than ever before. Di began to explore the white world around her. She looked, listened, and sat on her haunches to sniff the cold air.

She did not see the large white bird that sailed quietly over the snow toward her.

Its large black claws stretched out toward her back. Suddenly Di noticed a large shadow moving towards her. She rushed into the nearest tunnel, barely escaping the owl. This time the snowy owl would have to search for some other lemming to eat for its dinner.

Di's tunnels through shallow snow were light almost all of the time now. They had been dark all the time when she had first begun living on her own. Now it was almost too bright to see outside as the snow glistened and flashed in the sunlight.

Di, curious as ever, still regularly visited the snow surface. But after her encounter with the snowy owl, she was much more careful.

One day, as she gnawed on a willow branch, Di heard a new sound. It was a beautiful, melodic whistle. She hurried up to the surface to see what was making the pretty sound. The wind was howling outside the tunnel. It was hard to see through the blowing snow.

When she heard the beautiful sound again, Di spotted the singer. A small bird with striking black and white feathers and a small, cone-shaped bill was perched on top of a small snow bank near the entrance to one of Di's tunnels. A snow bunting.

After that day, Di noticed many changes in her world. The snow changed to ice in some places. Di could not dig through the ice. In other places, the ends of Di's tunnels simply disappeared. The tunnels in deep snow that were once warm, became wet and icy. Some filled up with water. Di got very cold when her fur got wet. She began to avoid the tunnels in the deep snow and started spending more time on top of the snow.

Her fur was now brown, so that she was camouflaged when she hid among the brown leaves of the tundra plants. None of the plants was more than a few inches tall. Di had to be very still when she wanted to hide.

This was a dangerous place and time for a lemming. Di saw, heard, or smelled an arctic fox almost once every week. Twice she smelled the horrid odor that she remembered from her days with her mother. Once she saw an owl carry off a lemming that had been too careless.

These events made Di wary. She sniffed the air often. She always looked carefully before going above the snow. She moved slowly. And she listened, even for faint noises.

Cack, cack, cack, get-back, tobaggo, tobaggo!

Di jumped nearly three inches off the ground when that loud cackling call exploded behind her. She raced under a tussock of grass and sat with her heart pounding.

Tobaggo, tobaggo, tobaggo!

Di carefully peeked out of her hiding place. She saw a ptarmigan eating willow buds. It had a brown head, a white body, and bright red combs over its eyes.

"Tobaggo, Tobaggo, Tobaggo!" it called.

Di saw a new bird every day. Most were flying to other places. They came, and left in great flocks. Often she heard large flocks of birds flying over. Their wings whistled in the wind. And most of them called out. Honk! Honk! Quack ... quaaack, quaack. Phsss, phss, phss.

She heard the sounds during the sunlit day and in the short twilight of night. Perhaps Di did not know it, but spring had arrived with the birds.

CHAPTER 3
SUMMER – A DIFFERENT WORLD

The weather changed often as spring turned into summer. One day was warm and the snow melted. Then snow fell and the winds howled the next day.

Soon, however, Di could not find snow to tunnel through. She had to swim in places where she had once run through snow. She found flattened piles of wet grass in places where she once had built warm nests.

Di, like all the lemmings, was forced to move to high spots on the tundra. Water covered everything else. Di could not find many places to hide, because few plants grew on the dry spots of tundra. Usually she hid under the dry leaves of a grass tussock.

Soon, the song of the snow bunting and outbursts of ptarmigan were hard to hear, because the air was filled with the calls and songs of many kinds of birds.

Lapland longspurs flew high into the air to sing songs that sounded like ice tinkling in a crystal glass. Boom, boom, boom, the drumlike calls of pectoral sandpipers echoed across the tundra.

Dunlin sailed into the air, then dove toward the earth. "Pssssssssssssssssh!" they whistled.

"Ah ha leeek, ah ha leek," called the oldsquaw ducks from every lake and pond. But even these were drowned out by the loud, haunting cries of loons: Hulawhoooo, Hulawhooooo.

The birds began nesting almost as soon as they arrived. Loons, geese, and eiders nested on the tiny islands in the midst of frozen tundra lakes. Sandpipers nested in the bare spots between patches of melting snow.

When another snow storm passed through, the tundra was blanketed with snow. The nests, eggs, and incubating birds were soon covered by wet snow. The birds could do nothing but wait for the snowstorm to stop. If they moved off their nests, their eggs would get too cold.

Di also waited for the snowstorm to end. The snow was too wet to tunnel through, so she hid under a grass tussock. When she felt the ground shaking, she poked her head out to look for a muskox. But she saw something else.

The long-legged animals trotting toward her were thinner than the muskox. They had short fur and thin antlers. They moved quickly, barely stopping to munch on the grasses and sedges. Di saw 20 caribou come close to her. Nearby, tens of thousands wandered over the tundra.

Di had much on her mind during these days of early summer. She had to dodge the hooves of the caribou. Jaegers, a new kind of bird predator, had appeared with the great hordes of other birds. Di had to be very careful to keep hidden from them and from owls. She listened for foxes and often sniffed the air for the smell of that other, mysterious danger.

Di found many new things to eat. She found green leaves and beautiful flowers on plants that had seemed dead during winter. The tundra was dotted with yellow, white, blue, and purple flowers. As Di feasted on this new variety of food, she grew large.

Many tundra animals, like the birds, were soon busy raising young. Within two weeks after the caribou arrived, almost every cow gave birth to a calf. The muskoxen had their calves in the willows down by the river.

Every day arctic foxes trotted across the tundra to carry lemmings, birds, eggs, and other prey to four young fox pups in their underground den.

Soon Di found a mate and, like the other tundra animals, began raising young. She and her mate dug a tunnel into the dry soil on the edge of a small rise in the tundra. Di discovered that just a few inches underground, the soil was still frozen solid. The frozen earth she found, called permafrost, underlies nearly all of the lowland tundra in Alaska.

Di made her nest soft and cozy with grasses, muskox fur, and ptarmigan feathers. Di and her lemming pups could not have had a warmer home.

As the days grew warmer, many kinds of insects began to appear. Bumblebees in yellow and black fur coats hatched from eggs that had been buried in the soil. They buzzed from one flower to the next. Yellow, blue, orange, white, and even black butterflies and moths came out of the chrysalises and cocoons in which, as larvae, they had slept through winter.

Flies and mosquitoes hatched from the eggs that had survived winter. They soon filled the air with a constant hum: Bzzzzzzz Bzzzzzzzz Bzzzz. Di heard their bzzzz whenever she was out of her burrow. She twitched her nose when one landed on it.

Every warm-blooded creature, from caribou to lemming and goose to longspur, knew the annoying sounds and bites of the mosquito hordes. Caribou often ran wildly across the tundra to try to escape these and other insects.

Di's summer season passed quickly. One day, the caribou herd headed inland on another part of their endless migration.

The eggs in hidden shorebird nests turned into long-legged, downy chicks, taller than Di. Soon after hatching, these chicks hurried after their parents in search of insects to eat.

Broods of ducklings followed their mothers around the edges of the tundra ponds. Meanwhile, flocks of male birds, and female birds whose nests eggs were eaten by predators, headed back south. Di watched long, single-file flocks of eiders fly past in a mirror image of their northward rush just two months earlier.

Areas that were flooded with water early in summer dried as the water slowly evaporated. Soon, white tufts of cotton topped the sedges and blanketed the tundra like patches of snow. Di found plenty to eat as the tundra's other flowers turned to seed pods.

In August, the temperature stayed below freezing for several days. Ice formed on the small tundra ponds, and frost covered the plants. Di listened, and she could hear no hum of insects. Summer had come to its end.

CHAPTER 4
FALL – A MYSTERY SOLVED

Di had to be very careful as summer turned to fall. More predators were looking for lemmings than ever before.

Not only were the adult foxes hunting, but their pups were out of the den and had begun hunting on their own. The jaegers' chicks were now large and needed more food than before. Both adult jaegers were busy hunting almost 24 hours a day in search of enough food for their demanding young.

The pair of snowy owls had raised five young, and all of them were out of the nest. Di often spotted their yellow eyes peering at her. Di was also careful because she sometimes smelled the terrible scent which she knew meant danger.

Each day the temperatures grew colder. The wind stung as it lashed across the land. Frost covered the tundra plants each morning. Small flurries of white snow swirled across the tundra. Di spent most of her time hiding amidst the cotton grass and eating the sweet berries that the frosts had ripened.

She also spent some time grooming her fur. Her short brown summer coat was falling out and a long white winter fur was growing in. Arctic foxes, tundra hares, and ptarmigan were beginning to turn white just like Di.

Di noticed that a period of darkness occurred and seemed to grow longer with each passing day. The tundra was quieter than it had been earlier. Not only were the insects silent, but the birds were too busy feeding to sing or call.

Each bird needed to put on a layer of fat. The fat would give it the energy needed for the long, long journey south. As each bird gained the needed weight, it lifted off and headed south. Di often heard the honking of a flock of geese that sailed overhead. "Honk, honk, honk!" they called as they left.

One day, Di awoke from a nap and felt that her world was somehow different. She ran to the entrance of her underground tunnel. It was covered by snow.

Di pushed her nose through the soft powder to try to find the outside world. She could tell from the dim reddish light that the short, sunlit part of the day was almost over. All around her the tundra was white. Snow was everywhere. It covered the yellowed leaves of the willows, the brown leaves of the sedges, the red of the bearberry, and even the brown patches of earth.

The wind was blowing again. The wind grew colder. More snow fell. The tundra lakes froze over. And the sun shone for a shorter and shorter length of time each day.

Di felt at home in this cold world. She tunneled one way and then the other through the snow. This was the world she had known as a young pup. She liked the warmth of the snow blanket and the darkness of her tunnels.

Di started building a warm nest of grasses in a spot she recognized as one she had used last winter. She also dug a tunnel to the surface of the snow so that she could occasionally go and look out.

On one of her visits to the surface, she saw a strange white animal she had never seen before. Its long body, short legs, and long tail tipped in black gave it an odd look. It moved by bringing its hind legs up near its front ones, then moving its front legs out. It looked a little like a very large and very fast caterpillar.

Always cautious, Di watched it carefully and sniffed the air. The animal was downwind of her, so she could not smell it. But she noticed that it was also sniffing the air, and it seemed to be moving right towards her. She backed further into her snow tunnel, but continued watching.

It was coming towards her even more quickly now. Something about its approach reminded Di of a hunting fox, so she decided to run away. She slipped down her snow tunnel away from the animal. Then she took a side tunnel that would lead to a spot downwind of the animal. Perhaps if she could sniff its scent, she would know what it was.

Di stopped and sniffed as she neared the end of the downwind tunnel.

She trembled when she recognized the odor that she had always feared. It was the smell of danger that she remembered from her earliest days in the nest with her mother. And now it was here – coming towards her!

She knew she must hide. But she had not had time to dig many tunnels in the snow. She peeked out the tunnel she was in and saw the tip of the weasel's tail disappearing down the entrance to the tunnel she had just been in. The animal's long narrow shape was just right for traveling in lemming tunnels.

Di suddenly knew that the weasel was hunting her. If she ran back down her tunnel she would run right into it.

Di decided to run over the snow surface instead. Scampering across the snow, she ran one way, then the other. The wind had formed a crust on the snow, so it was easy to run across it.

Di did not look back to see if the weasel was following. She just kept running as fast as she could.

The winds had blown the snow into drifts. Di had to run up and down, up and down over these. In her rush, Di did not see the drop-off near the edge of a frozen lake. She tumbled head over heels down the drop-off.

Down, down, down she went. When she finally landed in a snow bank, she lay stunned for an instant. Then she dove into the snow bank.

She dug as fast as she could and kicked snow to fill the tunnel behind her. At last she was too tired to dig further, so she stopped. Her heart was racing so fast she could hardly hear. But she listened carefully and sniffed the air. She heard nothing and could not smell anything.

Still she lay quietly. She did not want to make any noise that would help the weasel find her. She soon fell asleep.

Di jumped when she awoke. She calmed down only after sniffing the air. It smelled fresh and clean. Di had escaped the weasel. Now it was time to find food.

Di dug tunnels through the snow of this new area. When she finally had time to peek above ground, she felt the icy blast of winter winds and the freezing chill of below-zero temperatures. She could see only darkness. The wind howled. The ice groaned. Sometimes the sound of Di's teeth gnawing on willow twigs echoed through her tunnels; otherwise, winter was a silent season.

Di lived in her snow tunnels during these months of wind, snow, and darkness. The northern lights lit the dark sky over the tundra in February. Di cared for another litter of young under the snow. They would begin their lives as she had, in the darkness of a warm grass nest beneath a blanket of snow.

Pika Tag

2 EXTENSIONS

Section 4
TUNDRA ACTIVITIES

Grade Level: 3 - 6

State Standards: 5.E.1, 8.E.1. 8.E.2

NGSS: MS-LS2-5., MS-LS2-2.

Subjects: Science, physical education

Skills: Role-playing, observing, planning strategy

Duration: 30 minutes

Group Size: Whole class
Setting: Outdoors or multi-purpose room

Vocabulary: Burrow, habitat, pika, predator, prey, scree

Objective:
Students will name at least one example of a predator-prey relationship in an alpine tundra environment.

Teaching Strategy:
During a game, students role-play a predator-prey relationship found in alpine tundra environments.

Materials:
Large playing area; vests or bandannas of different colors to identify pikas, 1 hawk, and 1 weasel; poker chips or other "food" tokens; timer; picture or description of a pika.

Background:
See *INSIGHTS Section 4, Ecosystems: "Food webs." Also Pika Natural History* (below).

Pika Natural History:
(See also *Alaska Wildlife Notebook Series.*)
Pikas are small animals related to hares and rabbits. They live in **burrows** – tunnels dug between rocks on **scree** slopes in the alpine tundra.

Pikas gather grass every summer and dry it in the sun. Then they store the dried grass for winter food supply. Because pikas try to steal dried grass from piles made by other pikas, they constantly guard their own piles. A pika will chase away another pika "thief" that tries to steal from its pile.

Although several animals **prey** on pikas, principal **predators** are hawks and weasels. Pikas make a bleating cry, "Myaaa!" like a goat when they see a hawk, but they are silent and still when they see a weasel.

Procedure:
1. Explain that the class will play a game about pikas and their predators.

2. Simulate the scree slope **habitat** of pikas with 15 to 20 students joining hands and forming a large circle. Draw a line with chalk around the outside of this circle or mark it with a long rope. Inside the large circle, mark the burrow, an inner circle 3 to 5 feet (.9-1.5 meters) in diameter.

3. Outline a third circle on the floor away from the scree slope and burrow. This is the "predator's lunch" area

where pikas go after they are "caught" by a predator.

4. Pick one student to be a hawk and one to be a weasel; tell the rest they are pikas.

5. Tell the students about pikas and their predators. Explain the students' roles.

(a) ***Pikas:*** Each pika must leave its burrow to gather and dry food for the winter. Students move to the outer circle to pick up food tokens (*which the teacher scatters around the edge of the circle – the "large rocky slope"*).

Pikas can pick up *one* food token at a time and take it back to the outside edge of the burrow circle "to dry in the sun." When a pika has picked up and dried five food tokens, it can carry the food into the burrow and remain there, safe from the hawk. "Safe" pikas remain alert, looking for the weasel, and sit down whenever it appears.

Pikas gather grass every summer and dry it in the sun. They store the dried grass for winter food supply.

Pikas are vulnerable to weasels in the open and in burrows, but they can escape by hiding or sitting down. Pikas must give an alarm call when they see a hawk, and all pikas run into their burrow (*the inner circle*) for safety.

Because hawks have sharp eyes, they can spot and capture a pika even if pika-student is sitting down, but the pika is safe in the burrow. When a weasel or a hawk catches a pika, the pika is out of that round and should wait in the "predator's lunch" area.

Behavior review: Pikas pick up one food token at a time and return with it to the burrow "to dry in the sun." After gathering five tokens, a pika sits safe from hawks (but not weasels) in the burrow. Pikas cry and walk to their burrow to escape the hawk. Pikas sit to escape the weasel.

(b) ***Hawk:*** The hawk player stays outside the outer circle until she sees a vulnerable pika. Then, the hawk goes inside the circle and tries to tag that pika or any other unwary one. The hawk may not go inside the burrow – a pika can escape the hawk by running into the inner circle. After tagging a pika, the hawk walks around the outer circle once before re-entering to catch another pika.

(c) ***Weasel:*** The weasel player catches prey by being sneaky. It *quietly* sneaks into the pika colony, even into the burrow. A weasel can catch any unwary pika inside or outside the burrow, unless the pika sits down to hide before being tagged. After tagging a pika, the weasel must walk around the outer circle once before re-entering to catch another pika.

6. The game should be timed and end after 5 to 10 minutes. The winners are any pikas that stashed five food tokens and were not tagged by a predator. Play as many rounds as time allows.

VARIATIONS

A. After playing a couple of rounds, the group may modify game rules slightly to make the roles more equal. For example, the group could require the hawk to tag pikas with both hands instead of one, thereby making the hawk's task a little more challenging.

B. Pika players can steal food tokens from their neighbors' grass piles. A pika can only take one food token at a time. If a pika is caught stealing a food token, it must return the food to its owner.

NOTE: The result of stealing is usually that fewer pikas escape predators. They spend too much time watching other pikas and fail to notice the weasel or hawk.

Evaluation:

Students name one or more animals from an alpine tundra environment and one or more of its predators.

EXTENSIONS:

A. **Design a bar graph.** Using the results of the game, design a bar graph to display how many pikas survived and how many food tokens were taken during each round of the game.

B. **Imagine a tundra without predators**. Describe what might happen to the tundra environment if no predators existed. What would happen if the pikas' population crashed?

Curriculum Connections:

(See appendix for full citations)

Books:

Above the Treeline (Cooper)

Arctic Animals (Kalman)

Julie of the Wolves (George)

One Day on Pika's Peak (Hirshci)

Websites:

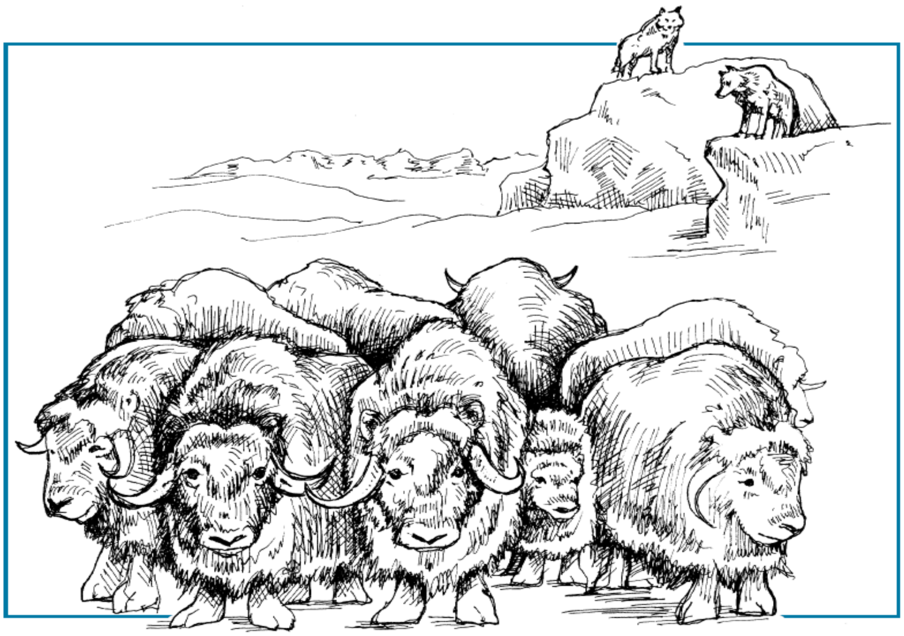
Pika and weasel fact sheets, Alaska Wild
Online <www.state.ak.us/adfg> (ADF

Teacher Resources:

(See appendix)

Muskox Maneuvers

2 EXTENSIONS



Section 4
TUNDRA ACTIVITIES

Grade Level: 4 - 8

State Standards: 5.E.1, 8.E.1.,8.E. 2

NGSS: 3-LS2-1, MS-LS1-4., MS-LS2-2 MS-LS2-4.

Subjects: Science, physical education

Skills: Observing, cooperating, analyzing, evaluating

Duration: 20 - 45 minutes

Group Size: At least 15

Setting: Indoors or Outdoors

Vocabulary: Adaptation, defense, extirpate, herbivore, predator, prey, reintroduction

Objective:

1. Students will describe adaptive behavior of prey and predators.
2. Students will describe how predators limit wildlife populations.

Teaching Strategy:

Students simulate adult and calf muskoxen and wolves to examine predator - prey relationships.

Materials:

Rag flags or survey tape of 2 colors for approximately half the class; objects such as Popsicle sticks, poker chips, or pieces of paper to represent food eaten by muskoxen; pictures of muskoxen and wolves.

Background:

See *INSIGHTS Section 4, Ecosystems.* Also *Muskox Natural History* (below).

Muskox Natural History

Muskoxen, or Umingmak (oo-ming-muck), are **herbivores** that live in tundra areas of Alaska, Canada, and Greenland. A full grown muskox male weighs between 600 and 800 pounds (272-565 kilograms), and an adult female weighs 350 to 500 pounds (159-227 kilograms).

Calves weigh about 19 pounds (8.6 kilograms) when born and reach 235 pounds (107 kilograms) at the end of one year. Adult muskoxen grow to 5 feet (1.5 meters) tall and are covered with long, shaggy hair. Muskoxen eat grasses, sedges, and woody plants.

Muskoxen live in small herds of 20 to 30 animals. Both parents and the herd defend the young by making a circle around the calves, or by standing in a line between calves and **predators**. They may lower their heads and butt wolves with their horns. They also lash out with their hooves. A muskox snorts and grunts.

Their **defense** strategy is quite effective against wolves, but it is not effective against human predators. When muskoxen gather into a defensive circle they are easy **prey** for hunters with rifles.

Muskoxen were overhunted and became locally extinct (**extirpated**) in Alaska during the 1850s. The muskox herd in Alaska today is the result of a **reintroduction** effort. Muskoxen were captured in east Greenland and moved to the Fairbanks area.

Offspring from that herd have been relocated to Nunivak Island, Nelson Island, the Seward Peninsula, and the Arctic National Wildlife Refuge. Muskox **habitat** remained relatively the same throughout their absence, so the herds have grown.

Procedure:

NOTE: This is a very active game which requires adult supervision and clear instruction.

1. Review the history and behavior of muskox in Alaska. Define the vocabulary terms.

2. Establish the boundaries of the playing area and scatter "food" (for example Popsicle sticks, poker chips, paper) over the area.

3. Divide the class into 3 groups: adult muskoxen, calves, and wolves. The group representing the adult muskox should be the largest.

4. Wolves and calves wear "flags" (flagging tape or cloth strips loosely tucked into their pockets or belt loops).

5. When play starts, muskoxen spread out over the playing field to quietly gather food. The wolves are out of sight. As the wolves attack the muskoxen the head cow gives the signal to move into defense positions.

6. Each group plays a specific role described below:

Adult Muskoxen**:** The adults, together, choose a head cow to look out for predators. When the head cow sees a predator, she will give a signal decided upon with the rest of the muskox. At the signal, all the adults circle round the calves to protect them from the wolves. The adults stand facing out toward the wolves and use their upper bodies to block the approach of the wolves.

The adults do not move their feet. They can, however, defend the calves with their hands by grabbing the flag from a wolf that is attacking the muskox (*no pushing or tackling*). If an adult succeeds in grabbing the flag, the wolf "dies" and moves to the sidelines until the end of the round. Taking the flag represents injuries muskoxen inflict using their horns and hooves.

Calves**:** Calves stand behind the adults with their hands on adults' waists. Because the calves depend on the adults, they cannot move around or make the adult move. Calves wear flags.

Wolves**:** Wolves try to sneak up on the muskoxen as they graze, so that they can "kill" a calf by grabbing its flag. Wolves arrange signals in order to work as a team. They try to move undetected close to the muskoxen before "attacking." If a wolf "kills" a calf, stop the play long enough for the body to be moved to the sidelines. Wolves also wear flags. Wolves howl and bark.

6. There are various ways the game can end:
• The muskox might kill all the wolves.
• The wolves might kill all the calves.
• The wolves might not be successful and would give up the hunt.
• The wolves might kill a couple of calves and drag them away to eat them. The hunt then ends, and muskoxen go back to grazing.

7. In discussion afterward, ask students what kind of **adaptation** the muskoxen used to protect their young, and what was the wolf's most successful hunting behavior. Ask students what the outcome would be if the wolves killed calves at every hunt. What do students think would happen to the wolves if they never killed a muskox calf? Does an unsuccessful hunt "cost" the wolf anything? *(loss of energy and potential injuries)*

Evaluation:

1. Students name a tundra prey species and its predator. Students describe adaptations: What kind of protection does the prey have or use? What does the predator do to catch the prey?

2. Describe an imaginary or unnamed tundra "prey" to the class, including its predator defense mechanisms. Students state the type of predatory technique an animal would need to capture the described "prey." Students list possible real-life predators.

Credit:
Adapted from "Muskox Maneuvers," *Project WILD*, Western Regional Environmental Education Council, 1992.

Curriculum Connections:
(See appendix for full citations)

Books:
A is for Arctic (Lynch)

Moose, Caribou and Musk Ox (Alaska Geographic Society)

Arctic Animals (Kalman)

Websites:
Muskox fact sheet in *Alaska Wildlife Notebook Series* online <www.adfg.alaska.gov>

"Muskox natural history" <www.muskoxfarm.org> (Alaska's Muskox Project)

Teacher Resources:
(See appendix)

The Dating Game

ALERT: ALASKA ECOLOGY CARDS OPTIONAL

Section 4
TUNDRA ACTIVITIES

State Standards: A.2

NGSS: 2-LS4-1

Subjects: Art, Language Arts, Science

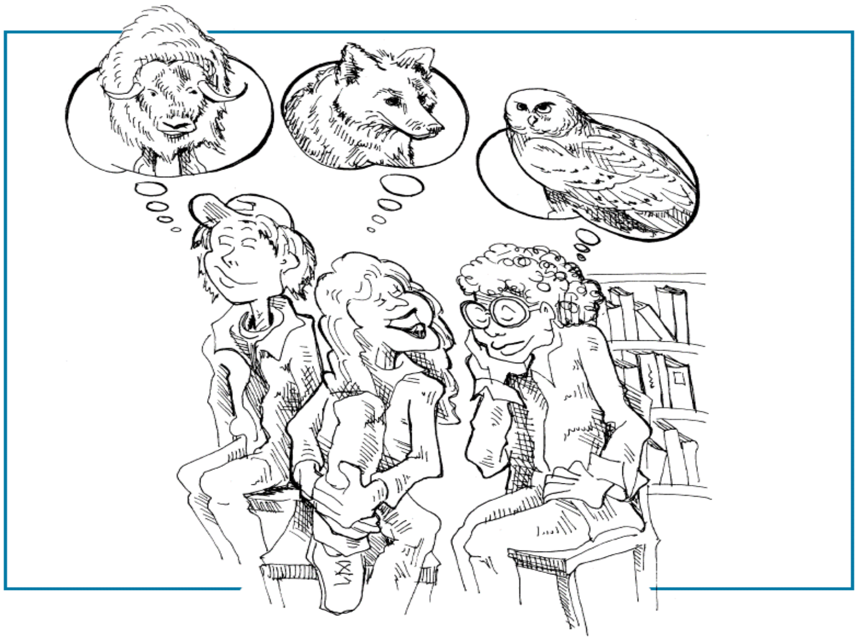
Skills: Identifying, classifying, creative dramatics, observing, organizing, reading, note taking

Duration: 2 sessions

Group Size: Partners, whole class

Setting: Indoors

Vocabulary: Names of tundra



Objective:
Students will reinforce their knowledge of tundra wildlife and habitat requirements by taking on the characteristics of tundra animals.

Teaching Strategy:
Students draw and label a tundra animal on one day. The next day, members of the class role-play pairs of animals and search for a match.

Materials:
Alaska Ecology Cards, *Wildlife Notebook Series*, or other pictures and information about tundra animals and their habitat.

Background:
See Insights *Sections 3, Life Forms and Adaptations;* and Insights *Section 4, Ecosystems.*

Procedure:
DAY ONE

1. Using your resource materials, discuss the animals that live on tundra. You may wish to supplement books or cards with postcards or colored illustrations *(see Curriculum Connections, following)*.

2. Divide the class into partners. Give each partnership 2 index cards and an animal. Both students draw the same animal and label their cards. Depending on their grade level, have students list several pertinent facts.

3. Play a simple memory matching game such as "Concentration" in order to reinforce the lesson.

DAY TWO

1. Review the illustrated cards with the class.

2. Shuffle the cards and pass out one card per student.

3. Seat the students in a circle. Each student has 10 seconds to physically imitate his or her animal. Other students remain silent.

4. Tell the students that they must find their "dates" – the match to their cards. They must imitate their animals so that their dates will recognize them.

5. Count to 10 while the students scatter around the room. When you reach 10, the hunt begins. Students may make animal noises, but no talking is allowed. The first team to find their match wins 3 points; the second team receives 2 points, the third team receives 1 point. Continue playing until everyone has a date.

6. Reshuffle the cards and play again.

VARIATION
This game was successfully adapted for a class of deaf students. They acted out the animals' visual features in great detail.

Evaluation:
Students name at least 10 examples of tundra wildlife.

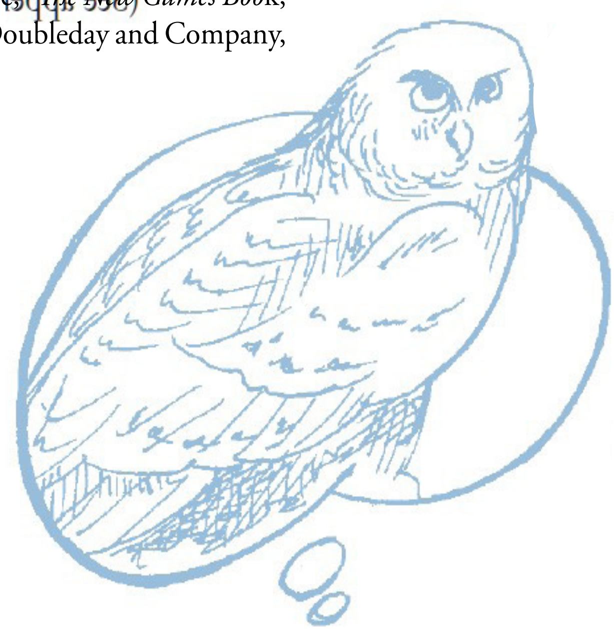
Credit:
Adapted from "The Mating Game," *The New Games Book*, edited by Andrew Fluegelman, Doubleday and Company, 1976.

Curriculum Connections:
(See appendix for full citations)

Books:
Alaska's Mammals (Smith)

Arctic Animals (Kalman)

Arctic Babies (Darling)



Mammals of Alaska (Alaska Geographic Society)

More Wild Critters (Jones)

A Naturalist's Guide to the Arctic (Pielou), 9-12

Wild Critters (Jones)

Websites:
Alaska Wildlife Notebook Series on line
<www.adfg.alaska.gov>

Arctic wildlife <arctic.fws.gov>
(Arctic National Wildlife Refuge)

Teacher Resources:
(See appendix)

Animal Charades

1 EXTENSION ALERT: ALASKA ECOLOGY CARDS OPTIONAL

Section 4
TUNDRA ACTIVITIES

Grade Level: K - 12

State Standards: **2**A
NGSS: 2-LS4-1

Subjects: Art, Language Arts, Science

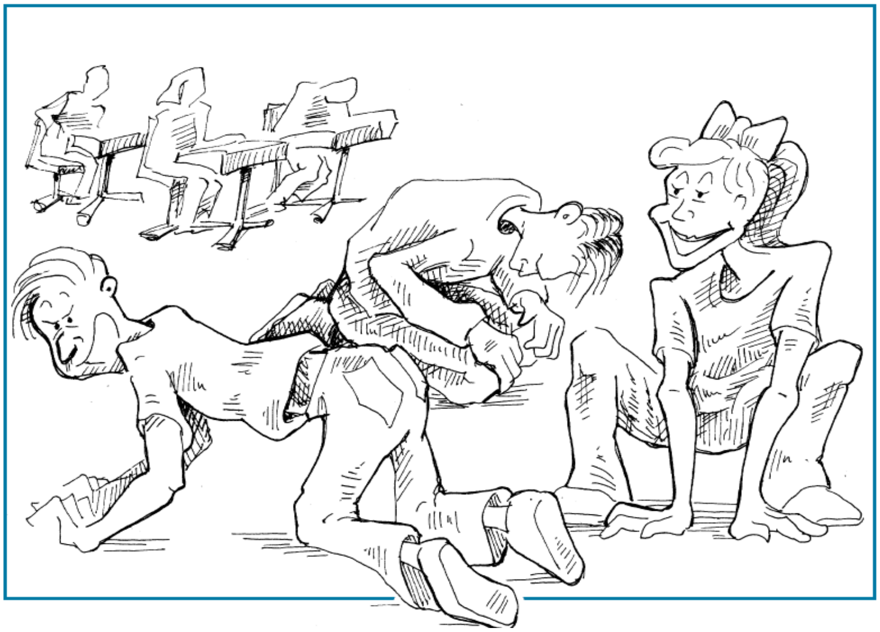
Skills: Identifying, classifying, creative dramatics, observing, organizing, reading, notetaking

Duration: Varies

Group Size: Individuals, whole class

Setting: Indoors

Vocabulary: Names of tundra wildlife



Objective:
Students will review their knowledge of tundra wildlife and habitat requirements by taking on the characteristics of tundra animals.

Teaching Strategy:
Students act out characteristics of tundra wildlife for their classmates, who try to guess what animal the actor represents.

Materials:
Alaska Ecology Cards, *Wildlife Notebook Series* or other pictures and information about tundra animals and their habitat.

Background:
See *INSIGHTS Sections 3, Life Forms and Adaptations;* and *INSIGHTS Section 4, Ecosystems.*

Procedure:
1. Hand out a tundra animal from the *Alaska Ecology Cards* or another picture of a tundra animal to each student. Caution students to keep their animals secret from the other students.

2. Ask students to read their cards and become familiar with the animals and their behavior. Encourage students to use resource materials to establish animal behaviors.

3. Students pretend to be the animals and act out the animals' behavior for the rest of the class. Students could assume a typical posture and then do some action typical of the animals they personify. If the class cannot guess the animals from the action, the students could make the animals' sounds.

Evaluation:
Students name at least 10 examples of tundra wildlife.

EXTENSION:
Develop animal clue cards. Students create clue cards for at least 10 tundra animals. The cards can be used to play a tundra board game or scoring game. To move or get a point, the player must name the animal the card describes.

Credit:
Adapted from "Animal Charades," *Project WILD*, Western Regional Environmental Education Council, 1992.

Curriculum Connections:

(See appendix for full citations)

Books:

Alaska's Mammals (Smith)

Arctic Animals (Kalman)

Arctic Babies (Darling)

Mammals of Alaska (Alaska Geographic Society)

More Wild Critters (Jones)

A Naturalist's Guide to the Arctic (Pielou), 9-12

Wild Critters (Jones)

Websites:

Alaska Wildlife Notebook Series on line
<www.adfg.alaska.gov>

Arctic wildlife <arctic.fws.gov>
(Arctic National Wildlife Refuge)

Teacher Resources:

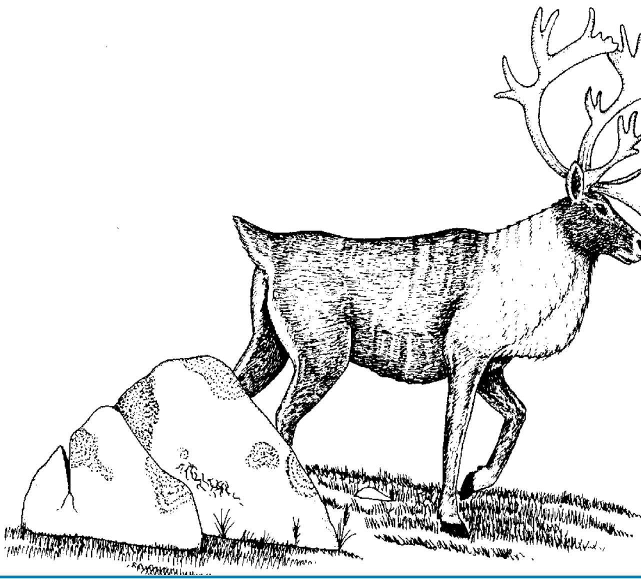
(See appendix)

Tundra soil teems with life.
One square meter near Barrow, Alaska,
within 2 inches (5 centimeters) of the surface
contained:

50,000 to 5 million nematodes
10,000 to 100,000 enchytraeid worms
10,000 to 80,000 mites
24,000 to a half million springtails
40,000 rotifers
15,000 tardigrades
700 fungus gnat larvae
smaller numbers of other insect larvae

Tundra Field Guide

2 EXTENSIONS _ ALERT: ALASKA ECOLOGY CARDS OPTIONAL



Section 4
TUNDRA ACTIVITIES

Grade Level: K - 12

State Standards: SL.K.1, SL.1.1 SL.2.1, SL.3.1, SL.4.1, SL.6.1 SL.7.1,SL.8.1, SL.10.1, SL.12.1

NGSS:2-LS4-1
Subjects: Art, Language Arts, Science

Skills: Identifying, classifying, writing, organizing, reading, note-taking

Duration: Several classes

Group Size: Individuals or small groups
Setting: Indoors or outdoors

Vocabulary: Food web, habitat, habits, names of tundra wildlife, predator, prey, traits

Objective:

Students will review and synthesize their knowledge of tundra wildlife and habitat requirements through writing.

Teaching Strategy:

Using wildlife reference materials, students develop and illustrate a field guide to the local tundra plant and animal communities.

Materials:

Alaska Ecology Cards, *Wildlife Notebook Series*, or other pictures and information about tundra animals and their habitat. Variety of field guides as examples *(see Curriculum Connections).*

Background:

See INSIGHTS *Section 4, Ecosystems,* and *Section 3, Adaptations.*

Procedure:

1. Students should be familiar with the format and function of field guides for animals, birds, and flowers.

2. Divide the class into small groups. Pass out an equal number of *Alaska Ecology Cards* or other reference materials to each group. (Students may also work independently.)

3. Students review their materials and sort out those organisms that occur in their local area. Some species, pika for example, have a limited distribution in Alaska and might not be found near your school.

4. Ask each group of students to make a field guide on local tundra wildlife using the appropriate *Alaska Ecology Cards,* and other reference materials. The guide could be about birds or another group of animals or it could include all of the living things in your area.

5. The field guide should contain information about how to identify each organism (**coloration**, **traits**), where to look for it (**habitat**), its size, what seasons it is present in your area, what it eats (**prey**), and who eats it (**predator** and **food web**).

6. Students can research this information from local experts

(*long-time residents and biologists*), reference books, the Internet, and observations. Students turn in their rough drafts for approval.

7. Their final drafts should include illustrations. Bind and "publish" the finished product – share at an open house or display in the hallway. You may wish to sell these for a local fundraiser.

Evaluation:

1. Review student field guides for accurate natural history and skill development.

2. Students name at least 10 examples of tundra wildlife.

EXTENSIONS:

A. **Tundra field trip.** Take a field trip to a tundra area and see how many of the living things shown in the field guide the students can find. Are there any common living things present that students did not show in their field guide? Encourage students to learn about these unknown plants, insects, or other organisms and then add them to their field guides. Invite community members or a biologist along to share their knowledge

B. **Develop field guide standards.** Students design their own criteria for excellence in a field guide and critique each others' guides.

Curriculum Connections:

(See appendix for full citations)

Books:

Alaska Trees and Shrubs (Viereck and Little)

Alaska Wild Berry Guide and Cookbook (Alaska Magazine)

Alaska-Yukon Wildflowers Guide (White)

Discovering Wild Plants: Alaska, Western Canada, the Northwest (Schofield)

Field Guide To Alaskan Wildflowers (Pratt)

Guide to the Birds of Alaska (Armstrong)

Mammals of Alaska (Alaska Geographic Society)

A Naturalist's Guide to the Arctic (Pielou), 9-12

Website:

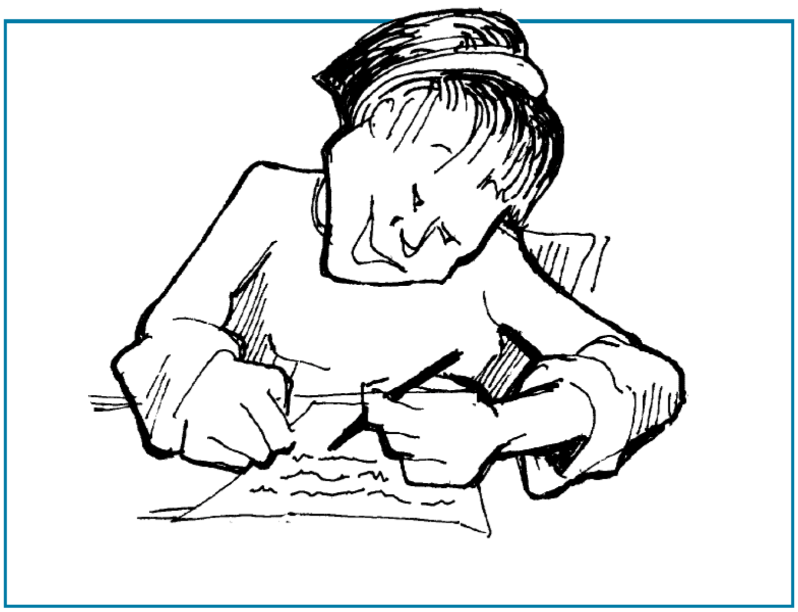
Alaska Wildlife Notebook Series on line <www.adfg.alaska.gov>(ADF&G)

Teacher Resources:

(See appendix)

Tundra Writing Adventure

1 EXTENSION __ ALERT: ALASKA ECOLOGY CARDS OPTIONAL



Section 4
TUNDRA ACTIVITIES

Grade Level: 4 - 12

State Standards: W.4.3, W.5.3 W.6.3, W.7.3, W.8.3, W.10.3 W.12.3

Subjects: Language Arts,

Skills: Identifying, classifying, creative writing, organizing, reading, note-taking

Duration: Several sessions

Group Size: Individuals

Setting: Indoors

Vocabulary: Varies

Objective:

Students will review and synthesize their knowledge of tundra wildlife and habitat requirements through writing.

Teaching Strategy:

Students research and write a short story about a tundra animal.

Complementary Activity:

"Di's Story" *in this section.*

Materials:

Alaska Ecology Cards, *Wildlife Notebook Series*, or other pictures and information about tundra animals and their habitat. Copy of "Di's Story" *(guided imagery in this section)* or other natural history stories *(see Curriculum Connections, following)* to read aloud.

Background:

See *INSIGHTS Section 4, Ecosystems,* and *Section 3, Adaptations.*

Procedure:

1. Read aloud a chapter of "Di's Story" or *One Day In the Alpine Tundra*. Students should listen for details about the animal and the animal's environment.

2. In order to write a **realistic** story, students will need to know something about the animal they choose as the main character for their story and something about the environment in which it lives. Research if necessary.

3. Discuss story elements: who, what, when, where, why, and how. Discuss some possible plots and adventures. For example, hare escapes predators; caribou migrates; pika prepares for winter. The story should include a main character, a setting of alpine or lowland tundra, a beginning, a middle, and an end.

4. Encourage students to write realistic stories. Discuss the term "realistic" carefully. Discuss examples of realistic stories such as *Caribou Journey* versus those with fantasy characters such as *The Three Little Pigs*. Encourage students to imagine that they are the animals they are writing about and imagine what the animals might see, hear, smell, and

feel. This will help them imagine things to write.

5. Discuss **anthropomorphism**. Anthropomorphism is placing human emotion on animals. We do not know how animals feel about their experiences. Discuss students' choices in placing or not placing human emotion in their stories.

6. Write the following steps on the board:
(a) Choose a tundra animal to be the main character of the story. Research the facts about the animal and its life, and think about them. (Depth of research should be age appropriate.)

(b) Write a rough draft about a day, month, or year in the life of this animal. Provide information about who, what, when, where, why, and how.

(c) Edit the story with a partner. Does it make sense? Does it have a beginning, a middle, and an end? Check for correct spelling and punctuation.

(d) Both students have a conference with the teacher concerning the story and its corrections.

(e) Rewrite the final draft.

(f) Draw an illustration of the main character, or one event in the story, for the cover.

7. Bind the stories individually, or bind them together for a class book.

8. Ask students to read their stories to the class or to a class of younger students.

Evaluation:

Before the student writes the final, the teacher reviews the written information for accuracy of information, spelling, and punctuation. Similarly, oversee the illustration's accuracy.

EXTENSION:

Dramatize before camera or audience. Have students dramatize their stories and videotape or perform for a live audience.

Curriculum Connections:

(See appendix for full citations)

Books:
A Caribou Journey (Miller)

Flight of the Golden Plover (Miller)

One Day in the Alpine Tundra (George)

Polar Bear Journey (Miller)

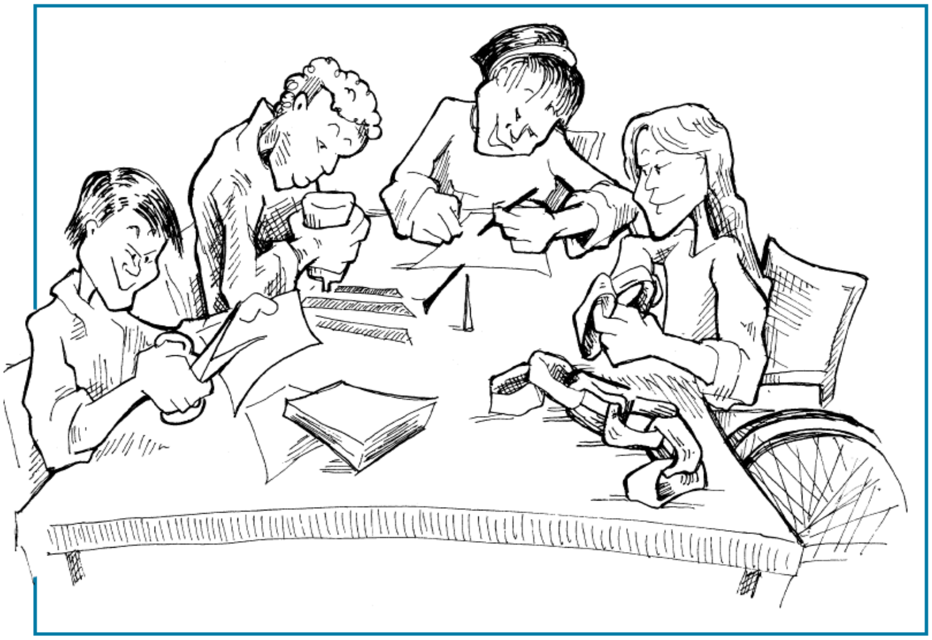
Teacher Resources:

(See appendix)

Survival Links

1 EXTENSION *ALERT: ALASKA ECOLOGY CARDS REQUIRED*

Section 4
TUNDRA ACTIVITIES



Grade Level: K - 4

NGSS: K-LS-1

Subjects: Science

Skills: Classifying, analyzing, comparing, fine motor coordination

Duration: Two 45-minute classes

Group Size: Individual or partners

Vocabulary: Consumers, carnivore, detritivore food chain, food web, herbivore, nonliving environment, omnivore, producer

Objective:
Students will construct a tundra food chain.

Teaching Strategy:
Students construct food chains in the form of traditional paper chains.

Materials:
Paper chain patterns *(following pages)* for each student, scissors, glue, *Alaska Ecology Card*s, butcher paper. OPTIONAL: crayons or markers, magazine pictures of tundra life forms.

Background:
See *INSIGHTS Section 4, Ecosystems – Community Connections.*

Procedure:
1. Hang 5 sheets of butcher paper around the room and label them: **nonliving environment**, **producers**, **herbivores**, **carnivores**, and **detritivores**. For very young students, label the paper "nonliving things," "green plants," "animals that eat plants," "animals that eat other animals," and "animals that eat dead things."

2. Students develop definitions (see *Glossary* and *INSIGHTS Section 4*). Write the responses, keeping them in the student's language.

3. Introduce a selection of the tundra species from the *Alaska Ecology Cards.* Review the animal's role in the food chain. Tape the ecology card or other pictures to the correct sheet of butcher paper. Ask the students to guess the connections – confirm or correct them.

4. Suggest that students start thinking which animals they will include in *their* food chain. Remind them that they need one item from each category; *for example, water, willow, moose, bear, and worms.*

5. Distribute the paper chain pages. Each page has an optional "Bonus" that will connect the 2 chains or start part of an additional food chain. *(See where they fit in the chart at the end of this activity.)*

6. Students may wish to color the pictures before cutting the strips. Students cut each strip and select one as a beginning link for the chain.

7. Students glue the ends together to form a paper ring. Connect the appropriate consumer as the next link in the chain. To verify connections, they can look at the *Alaska Ecology Cards* and pictures posted on the butcher paper sheets.

8. Display the chains. Ask students to predict what happens if a link of the chain is "broken" or disappears. Break a link to show the effects dramatically. Discuss events that could "break links."

VARIATION

Students decorate their pictures of the organisms in the food chain using other art techniques. Possibilities include paint, colored chalk, or glue with various materials *(colored candies, macaroni, hair, feathers, paper pieces, etc.)* to make mosaic pictures of each organism.

Evaluation:

Students describe the connections on their food chains.

EXTENSION:

Expand the chains with other tundra pictures. Gather tundra pictures that can be reproduced on additional paper strips to form more links in a food chain. Illustrations from the *Alaska Ecology Cards* may be reduced to the size of the other link pictures and copied for this activity.

The chart "Examples of Alaska Food Web Connections" *(following page)* has suggestions for additional connections. Combine individual chains into food webs wherever possible. Display the many connected links and chains and discuss what happens if links disappear or are "broken."

Curriculum Connections:

(See appendix for full citations)

Books:

Above the Treeline (Cooper)

Food Chains (Silverstein)

One Small Square: Arctic Tundra (Silver)

What are Food Chains and Webs? (Kalman)

Who Eats What? Food Chains and Food Webs (Lauber)

Teacher Resources:

(See appendix)

There are many food chains in the tundra. Almost every organism eats more than one kind of food, so each organism is part of several food chains. All the food chains together form the tundra food web.

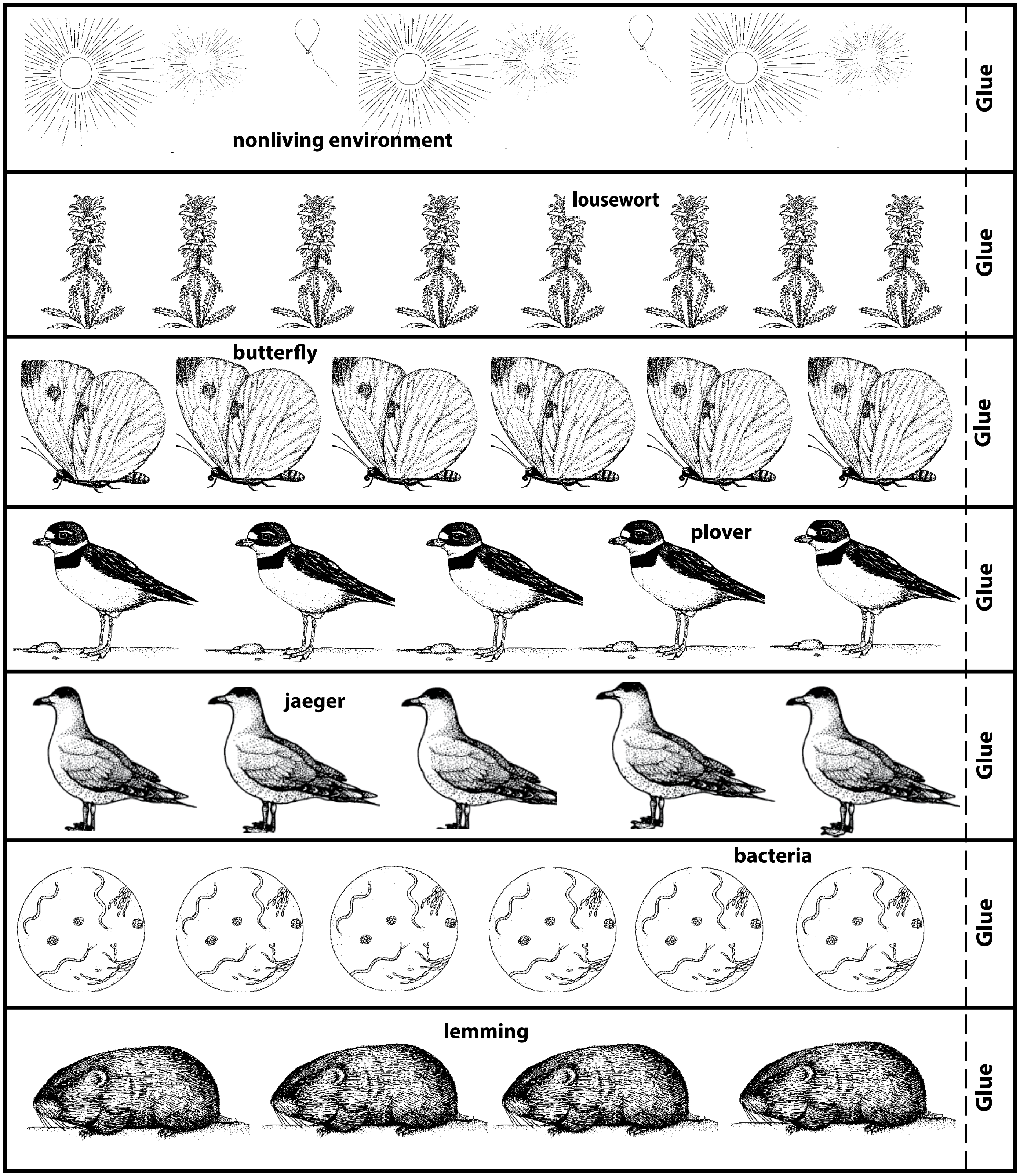
Examples of Alaska Food Web Connections

Food chains combine to form food webs. When you use the food chain/paper chains on the following pages, you may wish to expand the links into more extensive connections. The vertical columns on the following chart list some food- chain examples. Use the other foods listed below each living thing to make even more connections. You will find pictures of the listed organisms in the *Alaska Ecology Cards.*

Consumers – Living Environment	**Detritivore**	**springtail** *also eats* **any dead thing**	**fly** *also eats* **any dead animal**	**mushroom** *also eats* **any dead plant**	**bacteria** *also eats* **any dead thing**	**raven** *also eats* **any dead animal**
	Carnivore 2		**wolf** *also eats* **muskox, caribou, lemmings**	**owl** *also eats* **lemmings**	**jaeger** *also eats* **lemmings, redpolls**	
	Carnivore 1	**brown bear** *also eats* **sedge, grass, any dead animal**	**arctic fox** *also eats* **lemmings, weasel, any dead animal**	**weasel** *also eats* **redpoll, flies, springtail**	**plover** *also eats* **flies, springtails**	**wolf** *also eats* **arctic fox, caribou, lemmings**
	Herbivore	**caribou** *also eats* **willow, sedge**	**lapland longspar** *also eats* **lousewort, sedge**	**lemming** *also eats* **grass, lichens, lousewort**	**butterfly**	**muskox** *also eats* **grass, willow**
Producers	**Producer**	**lichen**	**willow**	**sedge**	**lousewort**	**grasses**

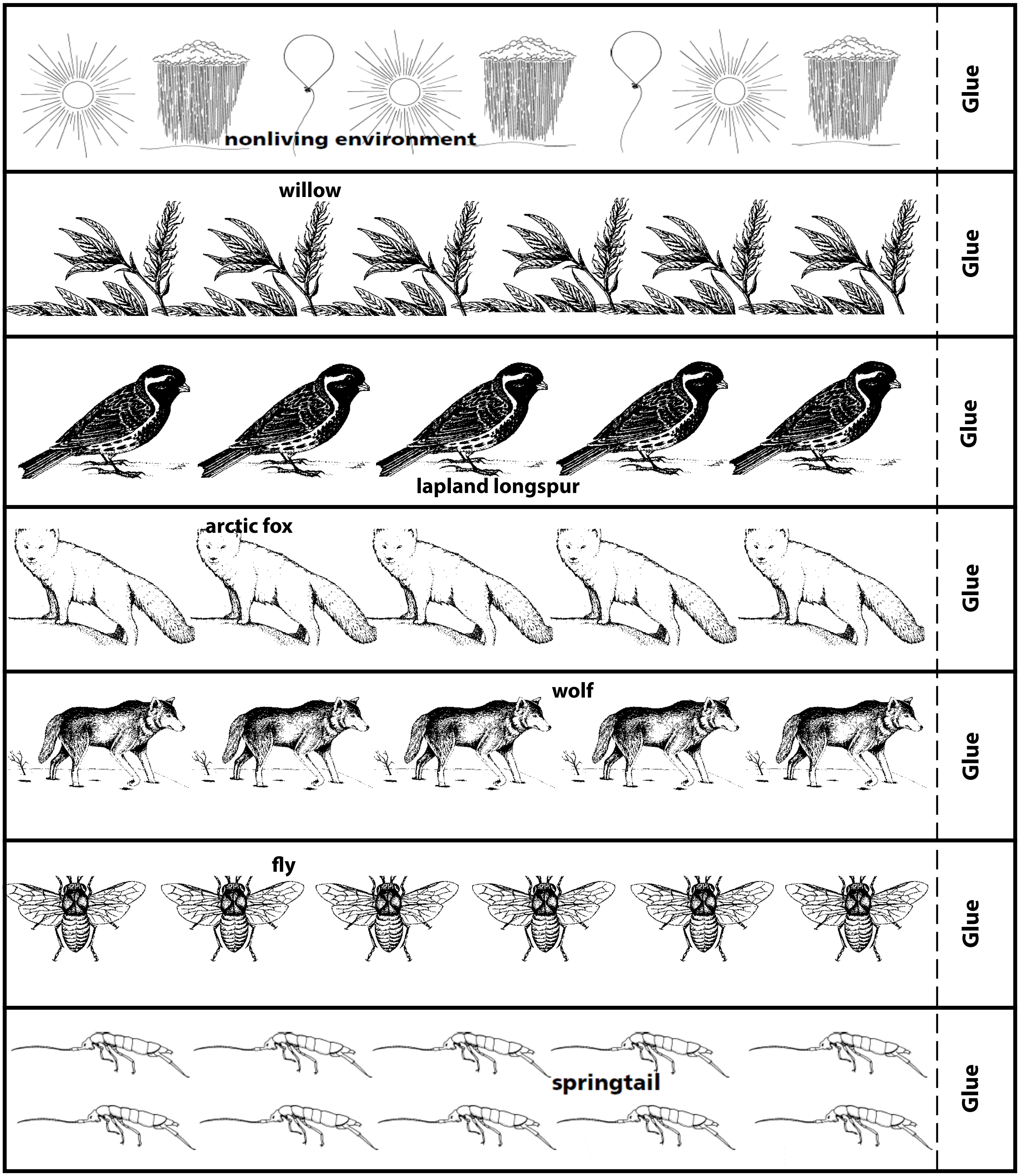
NONLIVING ENVIRONMENT: LIGHT • WATER • AIR • SOIL

Survival Link Paper Chains



Bonus

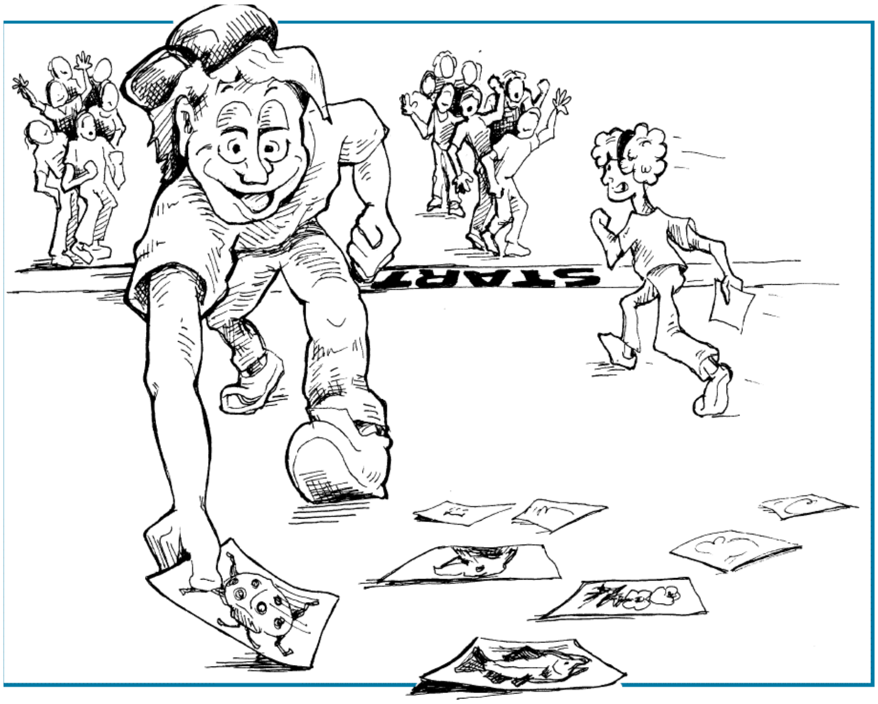
Survival Link Paper Chains



Bonus

Tundra Connections

ALERT: ALASKA ECOLOGY CARDS OPTIONAL



Section 4
TUNDRA ACTIVITIES

Grade Level: 4 - 10
NGSS: 5-LS2-1, MS-LS2-1. MS-LS2-2, MS-LS2-3

Subjects: Science, language arts
Skills: Comparing, inferring, predicting, reading, classifying, identifying
Duration: 1 or more classes
Group Size: Whole class
Setting: Indoors

Vocabulary: Carnivore, commensalism, consumer, detritivore, food chain, food web, herbivore, mutualism, nonliving, omnivore, parasitism, producer, symbioses

Objective:

Students will demonstrate awareness of food chain, food web, and symbiotic connections in a tundra ecosystem.

Teaching Strategy:

Students discuss various aspects of ecosystem connections and then play games to reinforce the concepts.

Complementary Activities:

"Food Chain Puzzles," "Tundra Food Chain Relay," and *"Tundra Ecosystem Solitaire,"* all in this section.

Materials:

Chalkboard

Background:

See INSIGHTS *Section 4, Ecosystems – Community Connections.*

Procedure:

1. Write the heading "Living/Nonliving Connections" on the board.

2. As a class, discuss the connections between them such as *wolves drink water, plants use minerals, and decomposers return minerals to the soil.* List these on the board.

Students should also come up with the following*: breathes air; drinks water; gets heat from the sun; makes food from air, water, and sunlight; gets minerals from the soil; and returns minerals to the soil.* Discuss how organisms are connected with or dependent upon the **nonliving** environment.

3. Write the heading "Living/Living Connections" on the board and ask students what connections they know between living things. As the connections are named, help students group similar connections together by placing all the connections involving one organism *eating* another in one group (**food chains**), and those connections involving one organism *helping* another in a second category (**symbioses**).

5. This "helping" category may be further divided into "they help each other," "one helps the other," and "one helps, the other harms." After students have given examples to fit all the categories, ask if they know the scientific names for them: **mutualism, commensalism, parasitism**.

6. The first categories of living/nonliving connections and living/living connections can be relabeled **food chain connections**. Explain how all living things are connected to others in the same community (or **ecosystem**) through food chains. List a complete tundra food chain and its interconnections – include the **nonliving environment**, a **producer**, an **herbivore**, a **carnivore**, and a **decomposer**. Discuss the exchange of energy and minerals through food chains.

7. The second type of connection can be relabeled symbioses, which literally mean "living together." Explain the three types of symbioses: mutualism, commensalism, and parasitism. Discuss how symbiotic connections differ from food chain connections. *(They involve something other than food.)*

8. **Students do one or more of three "Connection" activities —** "Food Chain Puzzles," "Tundra Food Chain Relay," and "Tundra Ecosystem Solitaire" *(all following in this section)*.

9. **After completing the "Connection" activities, students gather for a group discussion of the connections they have found**.

(a) Ask students to predict what living things would be affected if the nonliving environment of the tundra were changed. Suggest examples such as *if a marsh became polluted or if the air became polluted, how could this affect living things in the immediate and distant areas?*

(b) How would various changes in the tundra ecosystem affect the living things in it? *What if plant or mosquito populations declined or increased severely? What if precipitation dramatically increased or decreased? What if annual temperature patterns changed?* To what extent does one change impact the entire ecosystem?

(c) The changes just mentioned would impact the tundra ecosystem. Ask students to discuss how other ecosystems would be changed in other, distant places.

Evaluation:
Students make a bulletin board or wall-sized diagram of all the connections they know in tundra ecosystems.

Curriculum Connections:
(See appendix for full citations)

Books:

Arctic Animals (Kalman)

A Caribou Journey (Miller)

Food Chains (Silverstein)

Julie of the Wolves (George)

Never Cry Wolf (Mowat), 10-12

One Small Square: Arctic Tundra (Silver)

Tundra (Kaplan)

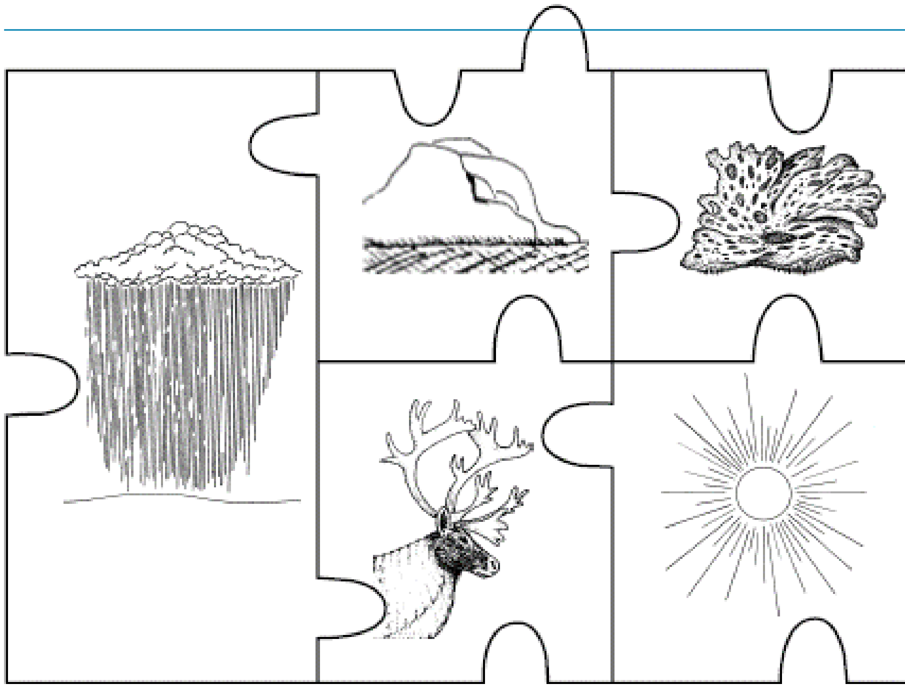
What are Food Chains and Webs? (Kalman)

Who Really Killed Cock Robin? An Ecological Mystery (George)

Teacher Resources:
(See appendix)

Tundra Food Chain Puzzles

Section 4
TUNDRA ACTIVITIES



Grade Level: 4 - 10
NGSS: 5-PS3-1., 5-LS2-1, MS-LS2-1., MS-LS2-2, MS-LS2-3, MS-ESS3-4.
Subjects: Science, language arts, physical education
Skills: Comparing, inferring, predicting, reading, classifying, identifying
Duration: 45 minutes
Group Size: Whole class
etting: Indoors
Vocabulary: Carnivore, commensalism, consumer, detritivore, food chain, food web, herbivore, mutualism, nonliving, omnivore, parasitism, producer, symbioses

Objective:
Students will demonstrate awareness of food chain, food web, and symbiotic connections in a tundra ecosystem.

Teaching Strategy:
Students put together puzzles to discover food chain and symbiotic connections among tundra organisms.

Complementary Activities:
"Tundra Connections," "Tundra Food Chain Relay," and *"Tundra Ecosystem Solitaire,"* all in this section.

Materials:
Tundra Puzzles *(following pages)*, photocopied and pasted on tagboard or heavy paper, cut out, and laminated; *Who Really Killed Cock Robin?* by Jean Craighead George *(see following Curriculum Connections)*.

OPTIONAL: copies of the *INSIGHTS Section 4, Tundra Ecosystems – Community Connections.*

Background:
See *INSIGHTS Section 4, Ecosystems – Community Connections.*

Procedure:
1. Read aloud the food chain mystery *Who Really Killed Cock Robin?* to introduce this lesson.

2. Review **living** and **nonliving** connections**, food chains** and **food webs**, and **symbioses**.

3. Give each student a puzzle piece. Ask students to find other students with connecting puzzle pieces in order to form the completed puzzle group.

4. Puzzle pieces have matching numbers if they are accurately connected. Ask each group to read the puzzle pieces and discover how the living or nonliving things pictured are connected to, interact with, or need each other. *INSIGHTS Section 4* should help them figure out how their puzzles fit together.

5. Ask whether any of the puzzles shows a complete ecosystem. *Students should recognize that each puzzle actually shows just a few of the interconnections in an ecosystem, and that a picture of all the connections in an ecosystem would be incredibly complicated.*

6. Discuss the following questions *(after one or more of the complementary activities)*:
(a)Ask students to predict what living things would be affected if the nonliving environment of the tundra were changed. Suggest examples such as *if a marsh became polluted or if the air became polluted, how could this affect living things in the immediate and distant areas?*

(b) How would various changes in the tundra ecosystem affect the living things in it? *What if plant or mosquito populations declined or increased severely? What if precipitation dramatically increased or decreased? What if annual temperature patterns changed?* To what extent does one change impact the entire ecosystem?

(c) The changes just mentioned would impact the tundra ecosystem. Ask students to discuss how other ecosystems would be changed in other, distant places.

Curriculum Connections:
(See appendix for full citations)

Books:
The Case of the Missing Cutthroats (George)

Food Chains (Silverstein)

One Small Square: Arctic Tundra (Silver)

Symbiosis (Silverstein) (Gr. 7-12)

What are Food Chains and Webs? (Kalman)

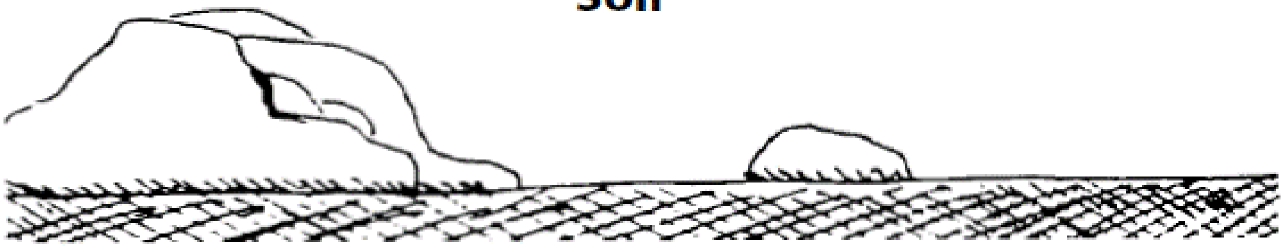
Who Really Killed Cock Robin? An Ecological Mystery (George)

Teacher Resources:
(See appendix)

Tundra Food Chain Puzzles

1

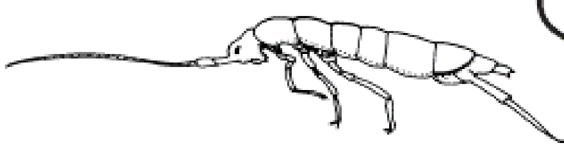
Soil



This soil contains minerals.

1

Springtail



Springtails return minerals to the soil. They feed on dead plants.

Willow

1

Willows make their own food using water, air, and sunlight. They take in minerals from the soil.

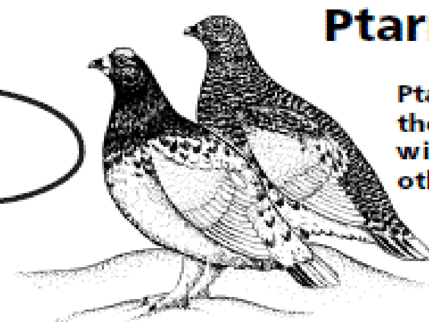
1

Longspur

Longspurs eat small insects such as springtails. They line their nests with ptarmigan feathers or caribou hair. This helps keep their eggs and chicks warm.

1

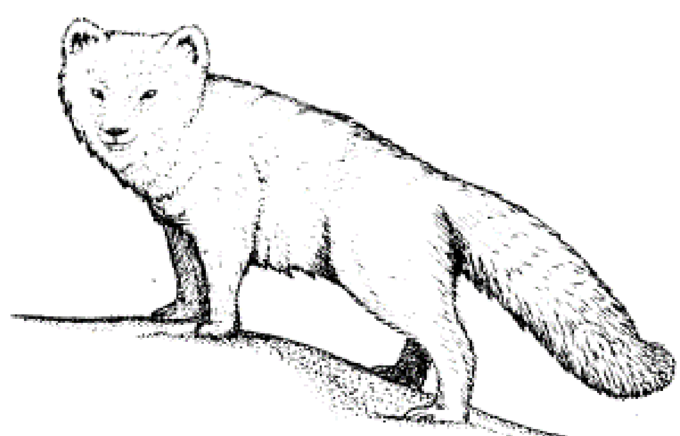
Ptarmigan



Ptarmigan eat the buds of willows and other plants.

1

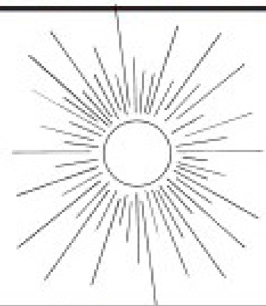
Arctic Fox



Arctic foxes eat a variety of foods. They hunt lemmings, small birds, ptarmigan, and eggs and scavenge dead animals.

Tundra Food Chain Puzzles

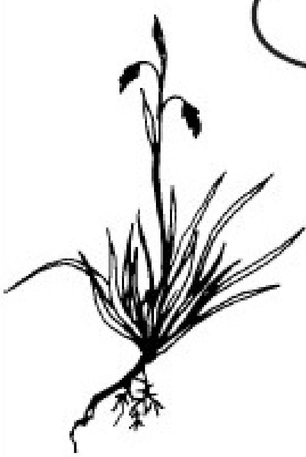
2



The sun provides energy in the forms of heat and light.

2

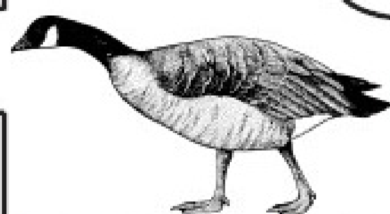
Sedge



Sedges make food from carbon dioxide, sunlight, and water. They take minerals from the soil. They take some oxygen from the air, but return much more.

2

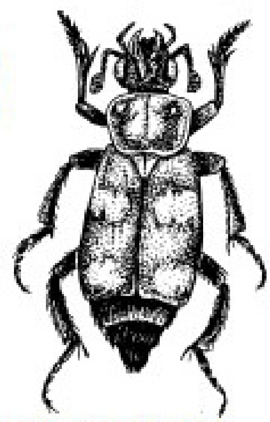
Goose



Geese eat grasses and sedges. They nest on an island in the middle of a lake or pond. They must have oxygen to breathe. Geese can keep warm if it is not too cold.

2

Carrion Beetle



Carrion beetles feed on any dead animal. They need oxygen to breathe. Beetles have a body temperature similar to that of their surroundings. They need heat to be active.

2

Brown Bear

Bears eat sedges and grasses, as well as berries, birds, mammals, eggs, and any dead animals they find. They need oxygen to breathe.

Air

2

Tundra Food Chain Puzzles

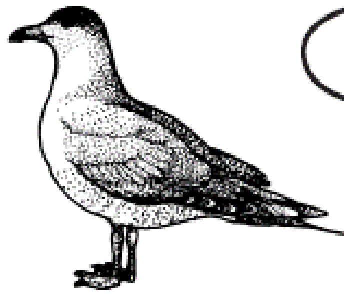
3

Lemming

3

Lemmings eat the green parts, seeds, and berries of plants, including bearberry

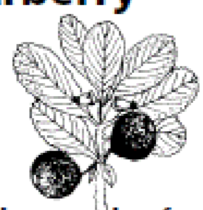
Jaeger



Jaegers feed on small mammals and small birds.

3

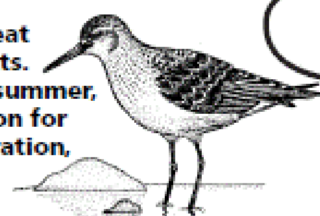
Bearberry



Bearberry makes food from air, water, and sunlight. They depend on mycorrhizal fungi to help them get minerals from the soil. This plant also depends upon an insect to carry its pollen to other flowers.

3

sandpiper



Sandpipers eat mostly insects. During late summer, in preparation for the fall migration, sandpipers will fatten up by eating berries. They will also eat berries when insects are scarce.

Moth

3

Adult moths feed on nectar from flowers. They carry pollen from one flower to another.

Fungi

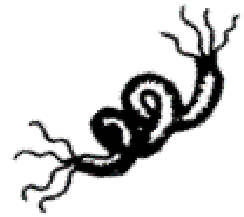
Fungi consume dead animals and plants as well as other waste materials.

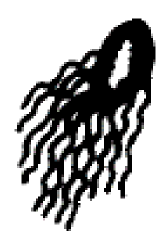
Tundra Food Chain Puzzles

4

Bacteria

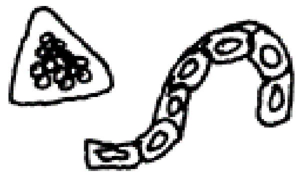
Bacteria feed upon and decay any dead material. Some kinds of bacteria live in the digestive tracts of caribou and help them digest their foods. Other kinds live inside other animals and cause diseases. Bacteria require moisture in order to live.





4

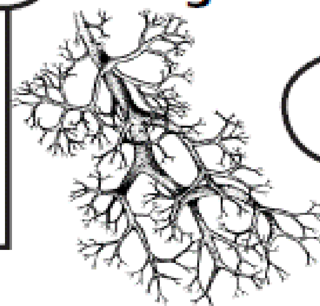
Algae



Algae make food from air, water, and sunlight. They can provide food to an organism that helps them. Algae must stay moist in order to live.

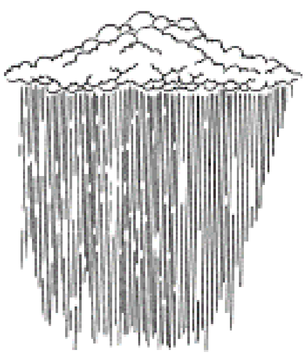
4

Fungi



Certain fungi live with certain algae. Together, they form lichens. The fungi prevent the algae from drying out and receive food in return.

4



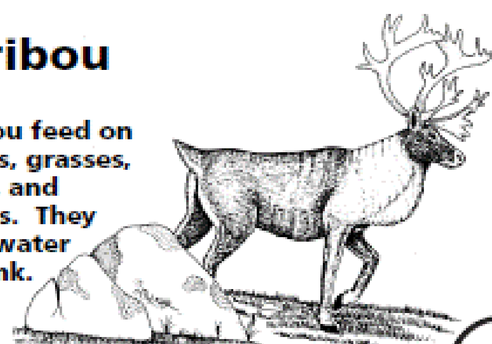
Water

Water occurs in the air as clouds, in rain and snow, and on the earth in streams, lakes, and oceans.

4

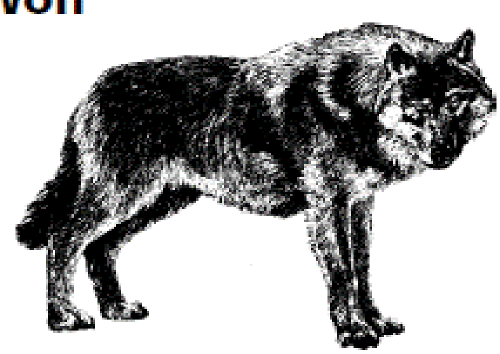
Caribou

Caribou feed on sedges, grasses, herbs, and lichens. They need water to drink.



4

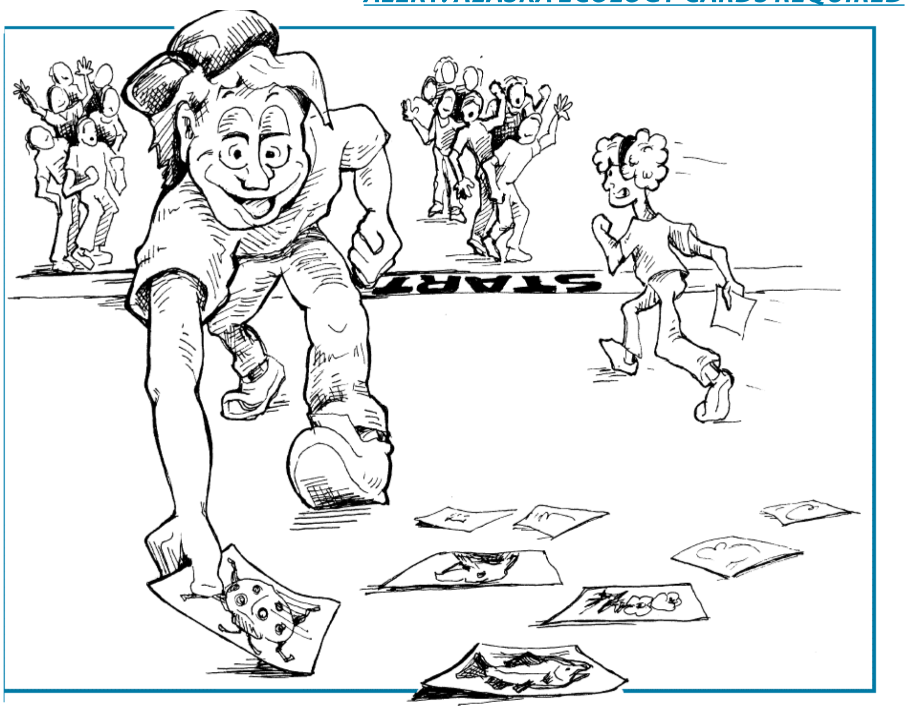
Wolf



Wolves feed mainly on large mammals, such as caribou. They need to drink water.

Tundra Food Chain Relay

ALERT: ALASKA ECOLOGY CARDS REQUIRED



Section 4
TUNDRA ACTIVITIES

Grade Level: 4 - 10
State Standards: 5.E.1, 8.E.1. 8.E. 2, 12. E. 1,12.E.2
NGSS: 5-PS3-1.,5-LS2-1,MS-LS2-1., MS-LS2-2,MS-LS2-3, MS-ESS3-4.
Subjects: Science, language arts, physical education
Skills: Comparing, inferring, predicting, reading, classifying, identifying
Duration: 2 or 3, 45-minute classes
Group Size: Whole class, small groups, individuals
Setting: Indoors/outdoors
Vocabulary: Carnivore, commensalism, consumer, detritivore, food chain, food web, herbivore, mutualism, nonliving, omnivore, parasitism, producer, symbioses

Objective:
Students will demonstrate awareness of food chain, food web, and symbiotic connections in a tundra ecosystem.

Teaching Strategy:
Students become familiar with tundra animals and food chain connections while actively engaged in a relay game.

Complementary Activities:
"Tundra Connections," "Food Chain Puzzles," and *"Tundra Ecosystem Solitaire,"* all in this section.

Materials:
Nonliving things, tundra plants, and tundra animals from the *Alaska Ecology Cards.*

Background:
See *INSIGHTS Section 4, Ecosystems – Community Connections.*

Procedure:
1. Divide the class into equal groups. Draw a starting line. Lay the *Alaska Ecology Cards* out on one side of a large playing area. Explain that the objective is for each team to assemble a tundra food chain. This should include something from the **nonliving environment**, a **producer**, an **herbivore**, a **carnivore**, and a **detritivore**.

2. One student in each team must run (*skip, hop, or walk*) to the other end of the playing area to find and bring back one wildlife card to his group. The next team player cannot leave until the previous player has returned with a card.

3. The team may keep the card if it connects with a card that their team already holds. *(Hint: Look for an organism that eats the object listed on the previously selected card.)* If the organism does not fit into the food chain, it must be returned to the card pile by the next runner.

4. Whenever a team has a complete food chain, they yell out "Food Chain." If the food chain is complete and correct, the team earns 10 points. The teams return their cards to the card pile, and another round starts.

5. If the food chain is incomplete or incorrect, the team loses five points, and the game resumes where it left off. To increase the level of difficulty, remove the cards that are already connected in each round.

6. Ask students to explain how this game is different from real food chains.

VARIATION
If you play this game inside your classroom, ask the students to move creatively as they collect their cards. *For example, students can walk like various animals as they return their cards.*

7. Discussion question *(after one or more of the complementary activities)*.

(a) Ask students to predict what living things would be affected if the nonliving environment of the tundra were changed. Suggest examples such as *if a marsh became polluted or if the air became polluted, how could this affect living things in the immediate and distant areas?*

(b) How would various changes in the tundra ecosystem affect the living things in it? *What if plant or mosquito populations declined severely? What if precipitation dramatically increased or decreased? What if annual temperature patterns changed?* To what extent does one change impact the entire ecosystem?

(c) The changes just mentioned would impact the tundra ecosystem. Ask students to discuss how other ecosystems would be changed in other, distant places.

Curriculum Connections:
(See appendix for full citations)

Books:
Food Chains (Silverstein)
One Small Square: Arctic Tundra (Silver)

Symbiosis (Silverstein), 7-12

What are Food Chains and Webs? (Kalman)

Teacher Resources:
(See appendix)

Tundra Ecosystem Solitaire

ALERT: ALASKA ECOLOGY CARDS REQUIRED

Section 4
TUNDRA ACTIVITIES

Grade Level: 4 - 10
NGSS: 5-PS3-1.,5-LS2-1,MS-LS2-1., MS-LS2-2,MS-LS2-3
Subjects: Science, language arts, physical education
Skills: Comparing, inferring, predicting, reading, classifying, identifying
Duration: 2 or 3 45-minute classes
Group Size: Whole class, small groups, individuals
Setting: Indoors/outdoors
Vocabulary: Carnivore, commensalism, consumer, detritivore, food chain, food web, herbivore, mutualism, nonliving, omnivore, parasitism, producer

Objective:
Students will demonstrate awareness of food chain, food web, and symbiotic connections in a tundra ecosystem.

Teaching Strategy:
Students collect groups of cards that form food chains and symbiotic relationships in matching sequence.

Complementary Activities:
"Tundra Connections," "Tundra Food Chain Puzzles," and *"Tundra Food Chain Relay,"* all in this section.

Materials:
One set of *Alaska Ecology Cards* cut out and laminated, plus 10 additional cards showing the nonliving environment; copy of game rules.

Background:
See *INSIGHTS Section 4, Ecosystems – Community Connections.*

Procedure:
The object of the game is to turn over all the cards in the piles and to earn points by making **food chains** and **symbiotic** matches of the organisms shown on the cards.

SINGLE PLAYER VERSION:

1. Shuffle the cards and count out 5 piles of 5 cards each, face down. Turn over the top card in each pile.

2. Any **nonliving** environment card or any **detritivore** card that is face up is then moved, face up, to form the base of a face-up pile above the other card piles.

3. Any face-up card that is connected to a card in the face-up piles (by a **food chain** or **symbiotic** connection) can be moved on top of the card to which it connects.

4. Whenever the top card is moved from a pile, the next card can be turned over.

5. If no other moves can be made, the player counts through the leftover stack. The player tries first to play every third card. The player continues until she is unable to move any more cards or turn over any new ones.

6. The player then adds up her score as follows: one point for each card in a complete food chain; 2 points for each symbiotic association. Incomplete food chains – *for example, missing the nonliving environment or a detritivore* – do not count.

TWO OR MORE PLAYERS:

1. Shuffle the cards and count out 5 piles of 5 cards each, face down. Turn over the top card in each pile.

2. Any **nonliving** environment card that turns face up on the set-up is reshuffled into the deck and a new card from the deck is placed face up on that pile.

3. Each player moves cards around on his turn only. He can move any top card connected to one of the other face-up cards. Either card may be moved on top of the other card to which it connects.

4. Whenever the top card is moved from a pile, the next card in the pile is turned over.

5. If a player does not see any move, she may turn over one card from the shuffle deck. If she cannot move this card, play passes to the right.

6. Whenever a nonliving card turns up, the active player can collect it, and begin collecting food chains and symbioses. He places the nonliving card face-up, in front of himself. He can then move cards from the central piles onto his nonliving card to form a food chain: *producer, herbivore, carnivore, detritivore*.

7. The cards must be moved in order. A carnivore card cannot be collected until producer and herbivore cards are collected. Also, if a player finds a card showing an organism that is symbiotic with an organism in food chains she has already collected, she may collect that card.

8. At the end of the game, players add up their scores as follows: 1 point for each card in the incomplete food chains they have built; for each complete food chain of 3 cards – 5 points; 4 cards – 7 points; 5 cards – 10 points; 6 cards – 15 points. Award 5 points for each symbiotic association in a player's collection. The player with the most points wins.

9. Discussion questions *(after one or more of the complementary activities)*:

(a) Ask students to predict what living things would be affected if the nonliving environment of the tundra were changed. Suggest examples such as *if a marsh became polluted or if the air became polluted, how could this affect living things in the immediate and distant areas?*

(b) How would various changes in the tundra ecosystem affect the living things in it? *What if plant or mosquito populations declined severely? What if precipitation dramatically increased or decreased? What if annual temperature patterns changed?* To what extent does one change impact the entire ecosystem?

(c) The changes just mentioned would impact the tundra ecosystem. Ask students to discuss how other ecosystems would be changed in other, distant places.

Curriculum Connections:

(See appendix for full citations)

Books:

Food Chains (Silverstein)

One Small Square: Arctic Tundra (Silver)

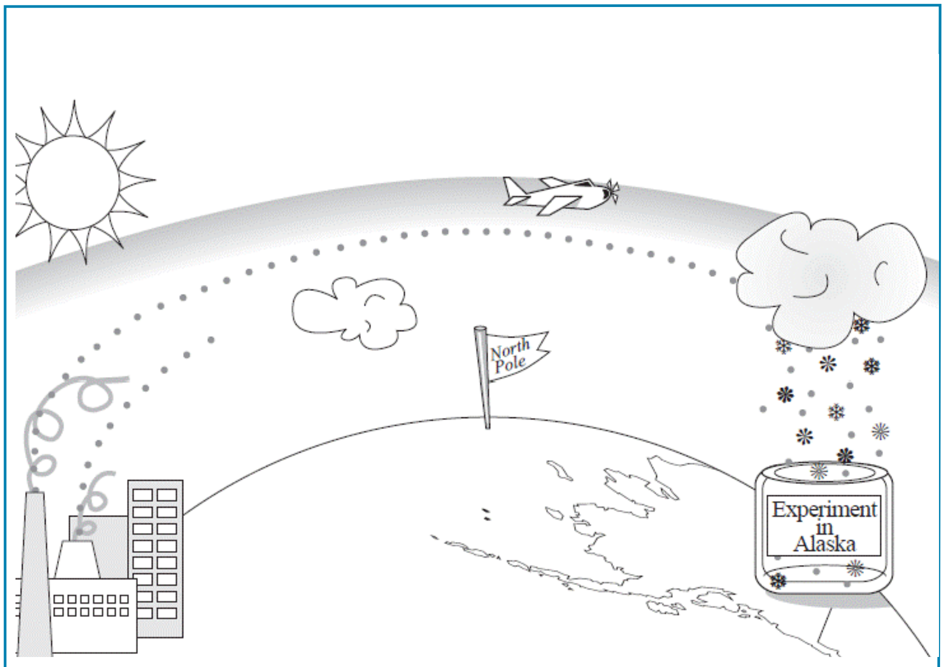
Symbiosis (Silverstein), 7-12

What are Food Chains and Webs? (Kalman)

Teacher Resources:

(See appendix)

How Clean Is Your Snow?



Section 5
TUNDRA ACTIVITIES

Grade Level: K - 3

State Standards: S A-15, S B-1, S B-5, Geo B-1, Geo E-5

Subject: Science

Skills: Analyzing, generalizing, observing

Duration: 20 minutes over two days

Group Size: Any

Setting: Outdoors/indoors

Vocabulary: Arctic haze, acid rain

Objective:

1. Students will analyze freshly fallen snow for dust particles and present or describe their results.

2. Students will recognize that air contains solid particles.

3. Students will list possible sources for air particles.

Teaching Strategy:

Students perform an experiment to demonstrate the presence of particles in falling snow.

Materials:

White paper towel or coffee filter; 2 clean, wide-mouthed jars; aluminum foil; funnel; chart paper; pencil; hand lens.

Background:

See INSIGHTS *Section 5, Human Impacts: "Arctic Haze"* and *"Acid Rain."*

Procedure:

1. Ask students to predict how much dust or solid particles are in fresh snow. Record their predictions.

Students often assume that fresh falling snow is "clean," and snow that has been laying around is dirty. Snowflakes, however, start to develop around a tiny, atmospheric particle. And dust that occurs naturally in our air also tends to get stuck to snowflakes. This phenomenon is even more evident in cities where roads, wood smoke, and exhaust create more particles in the air.

2. Leave a jar outside when it's snowing, and bring it inside when it's full.

3. Cover the jar with aluminum foil until the snow melts.

4. Place a funnel and a paper towel (or a clean coffee filter) over the second jar. Pour the melted snow into the filter.

5. When the paper towel or filter dries, examine what particles have been left. Examine the particles with a hand lens.

6. Discuss the results with the class:
(a) What are some natural causes for air particles? *(organic vapors from vegetation, wind blowing over bare ground, for example)*
(b) What are some human-made causes for air particles? *(vehicle emissions, oil or wood-burning stoves and heaters, smokestacks, for example)*

VARIATION FOR OLDER STUDENTS
Add globes, an atlas, and weather pattern maps from the Internet into the discussion.

Evaluation:
1. Students display their filters and explain the origins of the particles.

2. Students draw a picture of their schoolyard with the invisible particles made visible.

3. Students name possible sources for the particles found in the falling snow.

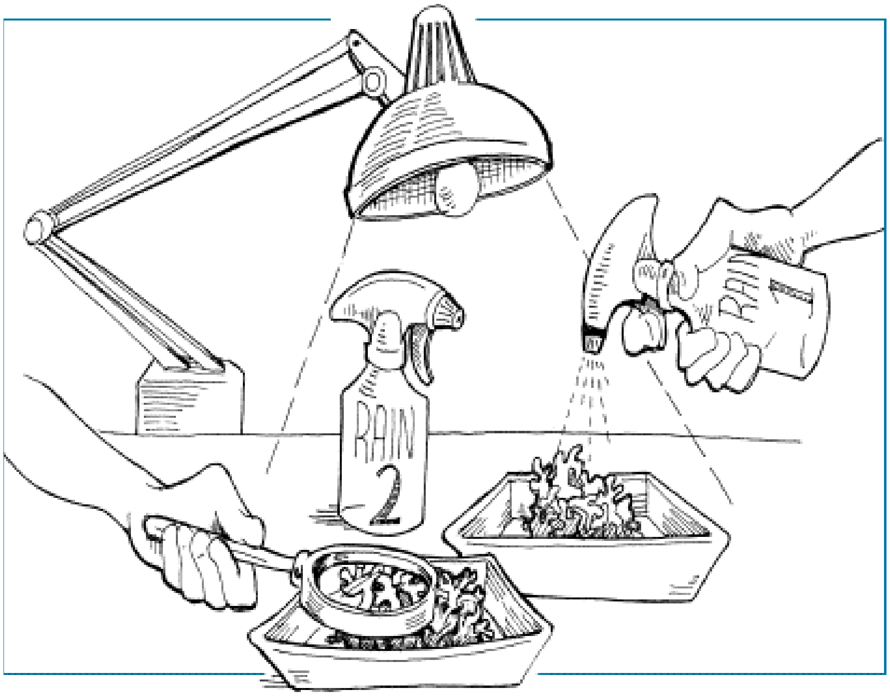
EXTENSION:
1. Place jars in different areas around your school or village and see if there's a difference in the number of particles.

2. Measure the number of particles in successive snowfalls. Make a chart of your results.

Teacher Resources:
(See appendix)

Lichens and Acid Rain

NON-LICHEN VARIATION and 1 EXTENSION



Section 5
TUNDRA ACTIVITIES

Grade Level: 4 - 9

NGSS: MS-LS2-4.,MS-ESS3-3., MS-ESS3-4,HS-LS2-7.,HS-ESS3-4.

Subjects: Science, social studies

Skills: Observing, using a control, inferring, predicting, measuring pH

Duration: Short lessons over two weeks
Group Size: Small
Setting: Indoors and outdoors
Vocabulary: Acid, algae, base, corrode, decomposition, fungi, lichen (fruticose, foliose, crustose), pH, symbiosis

Objective:
1. Students will describe the difference between an acid solution and a basic solution and give an example of each.

2. Students will describe some causes and effects of acid rain.

Teaching Strategy:
Students make "acid rain" and observe its effects on lichens and/or on soil and fruit.

Complementary Activity:
"Lichen Soil Builders" in *Section 2, Tundra Topography* and *Soil.*

Materials:
Two medium-sized pieces of **foliose** or **fruticose** lichens (all the same type, preferably a species of light coloration), 2 small pans, 2 plant spray bottles, many strips of pH paper, wood ashes, water, sunlight or a grow light, hand lens, an iron nail (not steel or galvanized), a square of chocolate.

A variety of solutions for students to examine including vinegar, cola drink, ammonia, lemon juice, soda, water, and local rain or snow meltwater.
Non-lichen Variation: 2 samples of soil and fruit.

Background:
See INSIGHTS *Section 5, Human Impacts: "Arctic Haze," "Acid Rain,"* and *"Radioactive Accumulation;"* and INSIGHTS *Section 2, Topography and Soil: "Lichens."*

Procedure:
IN ADVANCE, mix 1 tablespoon wood ashes with 1 cup water and pour into a plant spray bottle. Label it "Rain 1." Fill the second plant spray bottle with distilled water and label it "Rain 2." Prepare a well-lit spot (sunny window or grow-light) for the lichen samples.

See also the VARIATION (#6 - 8 of "Another Day") that uses fruit and soil instead of lichens.

DAY ONE
1. Show students the lichen samples and ask them what they are. Discuss how lichens live. Explain that the class is going to do an experiment on lichen growth using two kinds of rain water.

2. Place, or have students place, each of the lichen samples in a separate pan in the sunlit area (or under a grow-light). Label each "Lichen 1" or "Lichen 2."
Place the plant mister labeled Rain 1 next to Lichen 1 and the plant mister labeled Rain 2 next to Lichen 2. *Be sure it is clear which mister goes with which lichen, so students won't mix up their treatments.*

3. Explain that students have a new job as plant scientists to water (mist) the lichens with "rain" from the bottles. Lichen 1 should be misted only with Rain 1 and Lichen 2 only with Rain 2.

4. Students make and record predictions about what will happen to each lichen.

CONTINUING OBSERVATIONS

5. Each day students observe (with a hand lens) and record any changes seen in the lichens.

ANOTHER DAY

ACID versus BASE

1. Allow the lichen experiment to progress for a few days, until differences in the lichens are noticeable. Then, without initially referring to the experiment, explain to students that solutions of water mixed with other materials have a property we can't see, called **acidity**.

2. Because we can't see the difference between an **acid** and a **base** (non-acid), we use a special type of paper called pH paper to measure the acidity of solutions. Demonstrate the use of pH paper – blue indicates a non-acid solution, while pink indicates an acid.

3. Students measure the pH of lemon juice, vinegar, water, and meltwater or rain from outside the school. If desired, you can have students measure the pH of other solutions as well, for example soda and water, ammonia and water, and a commercial cola drink.

4. Explain that acids burn, or **corrode**, other materials. This can be demonstrated with an iron (not steel or galvanized) nail in a commercial cola drink, or a square of chocolate in vinegar. Explain that humans have acids in their stomachs to help them digest food.

5. Ask students why there was a difference in the two lichens after several days. Which rain do they think was acidic? Ask how many students have heard of **acid rain**. How might rain water become acidic? *Explain that acid rain is caused by air pollution from burning fossil fuels.*

NON-LICHEN VARIATION

6. Explain to students that acid rain not only affects lichens, it can also kill fish, because almost all fish cannot tolerate a pH much less than 5. It can also kill animals and other organisms living in the soil, for example, bacteria.

7. This can be demonstrated by spraying two samples of soil and fruit – one with "acid rain" and one with "normal rain." Observe the different rates of decomposition.

8. Discuss how declines in the populations of soil organisms would affect a tundra ecosystem. *Slower decomposition, with little or no recycling of minerals, leads to less plant production. Acid rain also leaches minerals out of the soil. Just as an acid can corrode a nail, acid rain dissolves minerals in soil. Then, when the rainwater runs off into lakes and rivers, it carries the minerals with it.*

OUTDOORS

1. Students look for differences in the numbers and kinds of lichens in several parts of town and away from town. *Different lichens respond differently to air pollution. In general,* ***fruticose*** *lichens are most sensitive to air pollution while* ***crustose*** *lichens are more tolerant.*

2. Can students find any evidence of local air pollution problems? If possible, have students examine the lichens at sites in and outside town, and near and far away from buildings producing high concentrations of smoke emissions; have them measure the pH of local ponds, rainwater, and snow.

3. Ask students to predict where they would find more lichens: near an airport or far away? Near a coal-fired power plant, or far away? In a town with automobiles and wood and oil stoves, or outside town?
- If tundra lichens die, how might this affect populations of caribou and other animals that eat lichens?
- What might happen to the populations of predators of these herbivores?
- What would happen to the soil if the lichens die?

4. Considering the undesirable consequences of acid rain, how could humans reduce it? Discuss ways to reduce air pollution: *by walking instead of driving, by not wasting electricity, by recycling (recycling aluminum reduces air pollution by 95 percent as compared to processing of new ore); by using and/or developing more efficient engines – for example, cars that get 30 instead of 10 miles per gallon of gas; and by building super-insulated homes and buildings that require less energy to heat or cool.*

Evaluation:

1. Students write a paragraph describing the difference between an acid and a base, giving an example of each, and listing at least three ways to reduce acid rain.

2. Students describe the causes and effects of acid rain.

EXTENSION:

Prepare public service announcements. Students work in teams of two to four to design and film a "Save the Tundra from Acid Rain" commercial or documentary. The class designs the evaluation criteria and critiques each production.

Curriculum Connections:

(See appendix for full citations)

Books:

Acid Rain (Edmonds)

Acid Rain (Patten)

Life in the Polar Lands (Byles)

Polar Lands (Aldis)

Media:

Acid Rain (Video) (Gr.5-12)

Acid Rain, the Invisible Threat (Video) (Gr.6-12)

Websites:

Alaska Science Forum
<www.gi.alaska.edu/ScienceForum>

Alaska Statewide Databases <sled.alaska.edu>

Lichen photos and information <www.ucmp.berkeley.edu/fungi/lichens/lichens.html>
(University of California Museum of Paleontology)

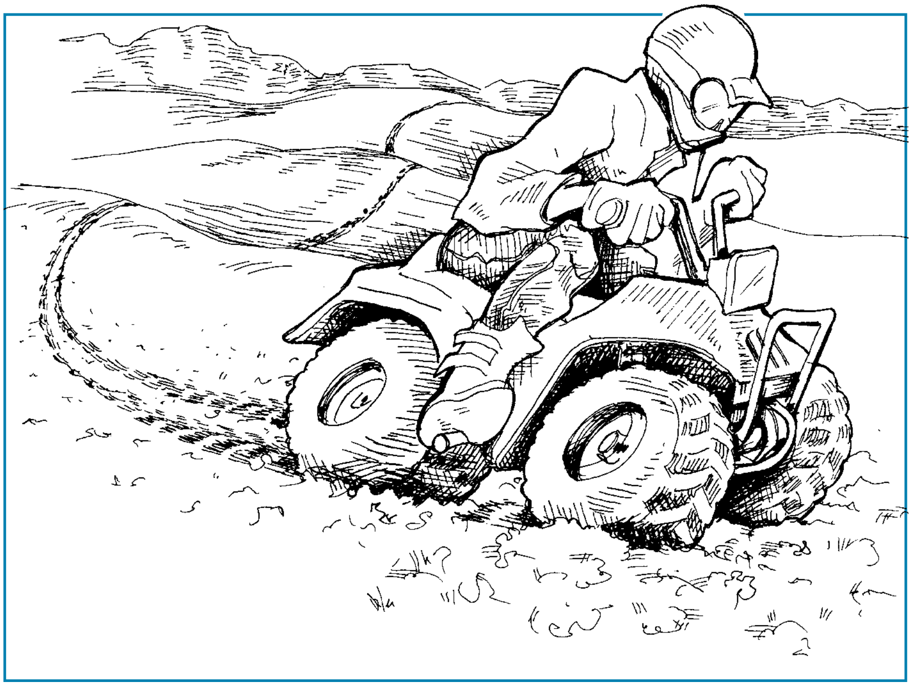
Teacher Resources:

(See appendix)

A majority of the tundra in Alaska is underlain by permafrost. Removal of tundra vegetation reduces insulation of the soil and causes the permafrost to melt. When permafrost melts, the ground slumps, creating a depression that grows larger each year.

Vehicles on the Tundra

3 EXTENSIONS



Section 5
TUNDRA ACTIVITIES

Grade Level: K - 12

NGSS: 5-ESS3-1.,MS-LS2-4., MS-ESS3-3.,HS-LS2-7.,HS-ESS3-4.

Subjects: Social studies, science

Skills: Observing, predicting, inferring

Duration: 30 minutes

Group Size: Whole class

Setting: Indoors

Vocabulary: Compaction, frost boils, high-center polygon, insulation, lichens, permafrost, tundra

Objective:
1. Students will investigate the effect of tundra vehicle traffic on vegetation and permafrost.

2. Students will describe ways to minimize damage from vehicles.

Teaching Strategy:
Students perform experiments with frozen soil to illustrate the effects of vehicle traffic on tundra.

Complementary Activity:
"Tundra Topography" or *"Heaving and Thawing in the Classroom,"* in *Section 2, Tundra Topography and Soil.*

Materials:
Two equal-sized baking pans, soil, water, freezer, several pieces of wool cloth or cotton quilt batting to simulate moss and lichens for covering the soil, a desk lamp with an incandescent bulb or a window with strong sunlight, *"Permafrost Features"* fact sheets from *INSIGHTS Section 2.*

Background:
See *INSIGHTS Section 5, Human Impacts: "Vehicles on Tundra;"* and *Section 2, Topography and Soils: "Permafrost Features"* and *"Lichen Soil Builders."*

Procedure:
IN ADVANCE, mix enough potting soil and water to fill two pans, then freeze them solidly. Cover the surface of both pans with a thick layer of woolen cloth or cotton batting to simulate tundra moss and lichen vegetation.

1. *IN CLASS,* review with students the concept that most tundra is underlain by **permafrost** – *permanently frozen soil* – and that much of the surface is covered by mosses and **lichens**. Show them the pans of frozen soil with the wool or cotton covering and explain that these represent models of the **tundra**.

2. Ask students to predict what a tundra area where a vehicle has been driven would look like. How would it compare with areas without traffic?

3. Remove the wool or cotton from one of the pans. Explain that the tundra area in that pan represents an area driven over by a large vehicle.

4. Place both pans under an incandescent light or in a warm, sunlit window. Ask students to observe what happens to the tundra in the "summer" when temperatures are warm. *Caution: if left too long, the frozen soil in both pans will melt*. Be sure to have students observe pans often and notice exactly when the unprotected frozen soil thaws.

5. Compare the soil in the two pans at that time. Students should note that the unprotected permafrost melted, leaving a soggy mess. Could this area be used as a road now?

6. Show students the photos on "Permafrost Features – Slumping Caused by Vehicle Tracks" fact sheet and discuss the effects of vehicle traffic. Besides melting the permafrost and changing the tundra, what other effects might the vehicles have? Ask students to predict the effects on lemmings, caribou, nesting birds, and plants.

7. Ask students to summarize the effects vehicles have on the tundra. Discuss ways to minimize the damage *(by not driving on the tundra, by driving on the tundra only in winter on thick snow, by using vehicles with big tires that are not as heavy, or by building roads with thick gravel beds that insulate the soil and then restricting vehicles to these roads).*

Evaluation:

Depending on grade level, students draw or write a description of the effect vehicles have on the tundra. Students describe ways to minimize the damage.

EXTENSIONS:

A. Design a tundra-friendly vehicle. Students design the perfect tundra vehicle – one that does little or no damage to the ecosystem. Students present their inventions.

B. Design a tundra-friendly road. Students design the perfect tundra road – one that does little or no damage to the ecosystem. Students present their designs. *(Students could send these on to oil companies or government officials.)*

C. Research industry solutions. Students contact oil companies and oil service companies to find out how they have engineered vehicles and roads to ease their impact on the tundra.

Curriculum Connections:

(See appendix for full citations)

Books:
The Arctic Land (Kalman*)*

Life in the Polar Lands (Byles)

Polar Lands (Aldis)

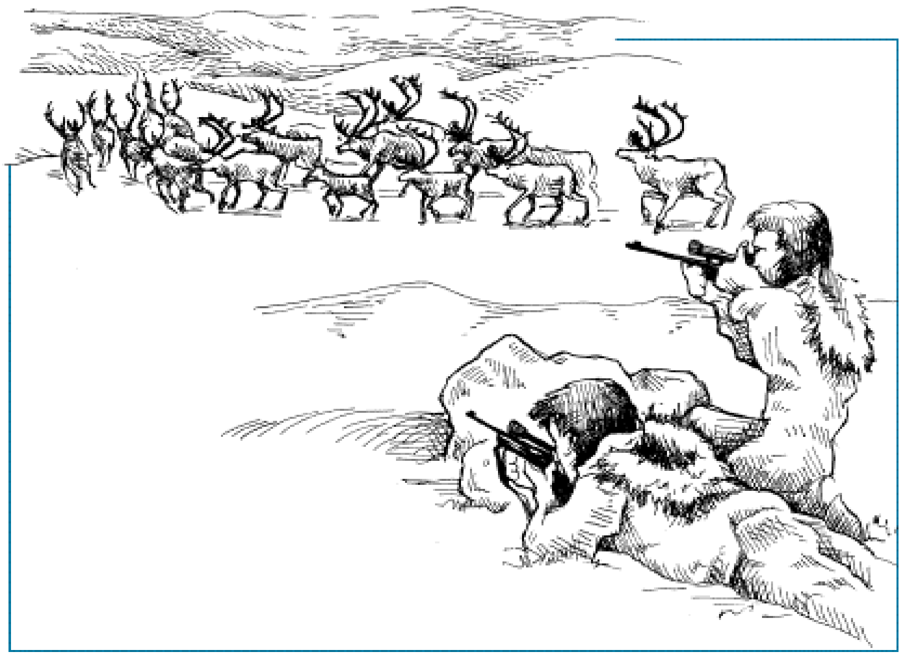
Websites:
Alaska Statewide Databases <sled.alaska.edu>

Staff-written Alaska newspaper articles: *Anchorage Daily News* archives <www.adnsearch.com> or *Fairbanks Daily News Miner* <www.newsminer.com>

Teacher Resources:

(See appendix)

Harvesting Wildlife



Section 5
TUNDRA ACTIVITIES

Grade Level: 4 - 12

NGSS: 5-ESS3-1.,MS-LS2-4., MS-ESS3-3.,HS-LS2-7.

Subjects: Social studies, science

Skills: Counting, reasoning, applying scientific knowledge to a social question

Duration: 60 minutes

Group Size: Whole class

Setting: Indoors

Vocabulary: bag limit, drawing permit, harvest, hunting season, permit, poaching, population

Objective:

Students will demonstrate that fish and wildlife harvesting must be done wisely and under some controls to protect wildlife populations.

Teaching Strategy:

Students "hunt" for wildlife under different conditions to illustrate consequences of controlled and uncontrolled harvesting of wildlife.

NOTE: Hunting and wildlife management has been a contentious issue in Alaska in the past. Before conducting this activity with your class, we suggest discussing the activity with community members and local biologists.

Materials:

A wall-sized tundra mural or large chalkboard sketch of tundra; 50 pictures showing one kind of tundra wildlife hunted by people (the caribou from the *Alaska Ecology Cards* for example); a container.

Slips of paper (placed in the countainer) equal to the number of students in the class with 2 of every 3 labeled **"This is not a permit."** and 1 of every 3 labeled **"Hunting Permit – You may harvest one animal."** Additional slips of paper (1/3 the total number of slips) labeled: **"This is not a permit – You harvest two animals anyway."**

Background:

See INSIGHTS *Section 5, Human Impacts: "Harvesting Tundra Wildlife."*

Procedure:

BEFORE CLASS, tape a number of wildlife cards *equal to the number of students in the class* to a tundra mural or a simple sketch of tundra on the chalkboard.

1. *IN CLASS,* ask students to pretend they are hunters or fishers who have come to **harvest** an animal from the tundra. Ask students if they think there should be any control over when they hunt and how many animals they take. Share responses and students' reasoning.

2. After each student takes ("hunts") one card from the mural, discuss what happened. *(No cards remain – no wildlife remains for their future use.)* Have students return the animals to the board.

3. Ask how the consequences of unlimited harvest could be avoided. *(If we limit the harvest adequately, animals may survive to raise more young and, thus, to replace the animals harvested by people.)*

4. Discuss how hunting and fishing licenses allow wildlife managers to limit harvest. *(If too many people want to harvest animals, we have to limit the number of hunters by giving out only a certain number of* ***permits*** *to hunt. The Alaska Department of Fish and Game does this in some cases by a* ***drawing permit*** *[lottery].)*

5. Ask students to count the number of animals on the board. This is the **population** of this animal. Then, ask each student to draw a slip of paper from the container. Only those who receive hunting permits can take animals. After they have chosen their animals from the board, ask all students to return their slips to the jar.

6. Explain that half of the animals remaining on the board are females, and they each produce one young the next spring. Place additional cards on the board to represent the young. Ask students to count the number of animals on the board now. *(It should be the same as before.)* Discuss why.

7. Ask students to hold another permit hunt, but this time add the slips that instruct certain students to harvest illegally (**poaching**). Repeat steps 7 and 8 – count number present, hold a harvest, show the results of animals reproducing, then recount the number present. What happened? Can students explain why there aren't as many animals as before?

Most tundra wildlife grows and reproduces slowly, compared to wildlife in more temperate ecosystems. For example, large fish in some tundra ponds are 40 years old or older. Fish of the same species in temperate regions reach the same size in only 10 years.

8. Repeat this process with the poaching slips 2 or 3 times to show the inevitable decline in the number of animals. Considering what they are seeing in this activity, do students think it is important to obey hunting and fishing laws? Why?

9. What are the consequences of people not obeying the laws? *(The laws are in place to protect whole populations and their habitat. Overharvest and habitat destruction can decimate a population.)* Discuss why tundra wildlife populations are particularly susceptible to overharvest *(INSIGHTS Section 5, Debate: Fragile or Resilient?)*.

VARIATION FOR OLDER STUDENTS:
Use this activity to introduce the concept of wildlife management. Place wildlife cards on board again, distinguishing male, female, and young animals.

Students work in teams of 2 to 4 to design a management plan stating how many animals can be harvested that year. It is assumed that class size will represent the number of hunters for the area. Students present their plans to the class.

Evaluation:
Students explain why there are limitations on hunting and fishing and describe what would happen if there were no limits to hunting.

Curriculum Connections:
(See appendix for full citations)

Books:
Arctic Hunter (Hoyt-Goldsmith)

A Caribou Journey (Miller)

Life in the Polar Lands (Byles)

Polar Lands (Aldis)

Websites:
Alaska Department of Fish and Game <www.adfg.alaska.gov> for current hunting seasons and regulations by species and game units.

Staff-written Alaska newspaper articles: *Anchorage Daily News* Archives <www.adnsearch.com> or *Fairbanks Daily News Miner* <www.newsminer.com>

Teacher Resources:
(See appendix)

Tundra Puzzlers

4 ACTIVITIES and 2 EXTENSIONS

Section 5
TUNDRA ACTIVITIES

Grade Level: 8 - 12
State Standards: RI.8.3, SL.8.1,SL.10.1 ,SL.12.1,RI.8.2,RI.10.2,
NGSS: MS-LS2-4.,MS-ESS3-4, HS-LS2-7.,HS-ESS3-4.
Subjects: Science, language arts
Skills: Synthesizing, inferring, predicting, reading, oral communication
Duration: 50 minutes
Group Size: Small or individuals
Setting: Indoors
Vocabulary: Acidic, active layer, alga/algae, alkaline, arctic haze, chlorophyll, fungus/fungi, half-life, harvested, home ranges, mortality, omnivores, percolate, permafrost, photosynthesize, radioactive isotope cesium-137, specific tolerances, symbiotic, survival rates, tundra

Objective:

Students will recognize that human activities affect tundra ecosystems.

Teaching Strategy:

Students use the story-problem information in the 4 Tundra Puzzlers to examine how certain human activities can have unexpected and long-lasting effects on tundra ecosystems.

Materials:

Copies of "Tundra Puzzlers" *(following pages)* for each student ["What Ecologists Have Learned" f*ollow each puzzlers*].

Background:

See INSIGHTS *Section 5, Human Impacts,* and *Section 2, Topography and Soil, "Permafrost Features,"* and article on thawing.

Procedure:

1. Organize students into small teams or as individuals. Hand out the puzzlers.

2. Explain that students are to use the facts provided to figure out a solution to the puzzler. To solve each puzzler, students will need to do the following:
(a) Read the information carefully.
(b) Look for connections in the information.
(c) Apply their knowledge of tundra ecology.
(d) Find and define all unknown words.
(e) Explain and defend their reasoning.
List these steps on the board.

3. Students read their puzzlers and facts and develop their own solutions.

4. Review each puzzler with the class. Ask those who worked on each puzzler to explain the puzzle and their solution or prediction. Discuss the puzzler with the whole class.

5. Read aloud the scientists' solutions. Compare them with the students' solutions.

Evaluation:

Students write a description of some of the effects of human activities on tundra ecosystems.

EXTENSION:

A. **Write pair of stories or plays.** Students write or act out 2 stories about changes to tundra as people settle into the area. In the first story, students focus on human actions where there is a lack of concern or understanding about the tundra ecosystem. In this story, short-term human needs take precedence over the health of the ecosystem.

In the second story, long-term health of the ecosystem is viewed in relation to human health. The community plans for the long-term health of both people and the ecosystem as a whole.

Follow these stories or plays with a discussion about responsible human action toward wildlife and the need for information and understanding about ecosystems.

B. **Compare ancient and modern impacts.** Students study the historic and traditional lifestyle of nomadic tundra peoples and the impact that lifestyle had on the tundra. Students then look at modern life in tundra communities and identify decisions and actions that can lessen harmful impacts on the tundra.

Curriculum Connections:

(See appendix for full citations)

Books:

Acid Rain (Edmonds)

Acid Rain (Patten)

Food Chains (Silverstein)

Into Thin Air: the Problem of Air Pollution (Kidd)

Vanishing Ozone: Protecting Earth from Ultraviolet Radiation (Pringle)

Food Chains (Silverstein)

Media:

Acid Rain (Video) (Gr.5-12)

Acid Rain, the Invisible Threat (Video) (Gr. 6-12)

Websites:

Alaska Science Forum
<www.gi.alaska.edu/ScienceForum

Alaska Statewide Databases <sled.alaska.edu>

Staff-written Alaska newspaper articles: *Anchorage Daily News* Archives <www.adnsearch.com> or *Fairbanks Daily News Miner* <www.newsminer.com>

Teacher Resources:

(See appendix)

Tundra Puzzler 1

TUNDRA AND PERMAFROST – ICY BALANCE

Background Information

• **Permafrost** – *perennially frozen soil* – underlies most of the **lowland tundra** in Alaska. Permafrost may be from 2 inches to several feet below the surface, depending on local environmental conditions. Generally, permafrost is nearer the surface on north-facing slopes and in sites where the soil is insulated by vegetation.

• Mosses, **lichens**, and flowering plants insulate the permafrost and help prevent thawing. They die when they are repeatedly crushed or trampled. They grow very slowly because of cold temperatures, short growing seasons, and the scarcity of minerals in tundra soils.

• All plants have **specific tolerances** for soil moisture. Some species grow only on dry soils, while others grow only on wet soils.

• Much of the lowland tundra in northern Alaska receives less than 5 inches (12.7 centimeters) of precipitation per year. This is equivalent to the amount of precipitation in a desert.

• Water from rain and melting snow drains into low-lying spots. Except for stream drainage, the annual precipitation in lowland tundra remains on top of the permafrost because water cannot drain through frozen soil.

• This layer of soil on top of permafrost is called the **active layer** because it thaws and refreezes each year.

• Water expands when it freezes, so that wet soil that is frozen takes up more room than does thawed wet soil.

• Water is an excellent conductor of heat energy. If you expose a pan of soil and a pan of water to heat, the water gets warmer faster and stay warmer longer. It absorbs and retains more heat from sunlight than the soil does.

THE PUZZLE

Based on the information given and your understanding of ecology, what changes in the tundra would you expect to occur after a large track vehicle was driven across the tundra?

What changes might you expect if reindeer or caribou were confined by fences, roads, or other obstructions to a small area of tundra for several days,? What would be the effects of a hiking trail across permafrost tundra?

If Alaska's permafrost melted, what would happen to buildings, pipelines, and highways?

Tundra Puzzler 1

TUNDRA AND PERMAFROST – ICY BALANCE

What Ecologists Have Learned

Disturbance of tundra vegetation by vehicle traffic or by repeated trampling by reindeer, caribou, or humans will kill plants and lichens. This removes a layer of insulation from the soil surface. As a result, the exposed soil thaws to a greater depth than do surrounding soils.

The thawed soil takes up less space than the frozen soil did originally; thus the thawed soil in the site slumps or subsides.

Water drains into the low spots created by the slumping. Although water may percolate through the active layer, it cannot seep through the underlying and surrounding permafrost.

The collected water absorbs heat from sunlight, so that underlying and surrounding permafrost is further melted.

When winter returns, the collected water and water-logged soil freeze and expand. The pressure of the expanding ice forces the surrounding soil out and upward, thus enlarging the low spot and creating mounds in the surrounding soils.

In spring, when the active layer thaws again, the water-logged soil in the site once more subsides and becomes a collecting pool.

Over years, this repeated freezing and thawing enlarges the low spots originally caused by a disturbance of the vegetation. Ultimately, a large area of formerly dry soil is converted to low-lying, wet or submerged soil.

The plants that previously grew on the spot cannot survive in the wet soil. They die and cannot recolonize the site. Although plants adapted to wet soil may invade, their colonization of the area is slow (due mainly to slow rates of plant growth in tundra environments).

Thus, as a result of the interconnections between vegetation, water, soil, and sunlight, the effects of a vehicle driving across permafrost tundra or of repeated and concentrated foot traffic may change permafrost laden tundra for decades or in some cases, permanently.

The effects of permafrost disturbance on poorly drained, ice-rich soils can be quite startling – mounds 10-50 feet (3-15 meters) in diameter, and up to 8 feet (2.4 meters) high, separated by trenches 1- 5 feet (.3-1.5 meters) wide, or pits 5-20 feet (1.5-6.1 meters) deep and 3-20 feet (.91-6.1 meters) across. On slopes, the thawing of permafrost can cause slope failures, mass earth movement, or landslides.

Tundra Puzzler 2

IS TUNDRA RADIOACTIVE?

Background Information

• The **radioactive isotope cesium-137** is a product of atomic fission reactions such as those in the explosion of nuclear weapons and in nuclear power plants. It has a **half-life** of 30 years, which means that it loses half of its radioactivity every 30 years. After 60 years, it still has 1/4 of its original radioactivity, and after 90, it has 1/8 its original radioactivity.

Cesium-137 has been released into the atmosphere by the testing of atomic weapons along the Pacific Rim and from the 1986 explosion at Russia's Chernobyl nuclear power plant. Much of the atmospheric testing occurred in the late
l950s and early l960s.

• Cesium-137 has chemical properties that make it react with other chemicals in ways similar to the way potassium reacts with other chemicals.

• **Lichens** get the minerals they need mainly from rain and snowmelt.

• Potassium is an essential mineral for living things, including lichens. It occurs in the cells and fluids of living things. In mammals, the amount of potassium in the blood is regulated by the kidneys. Excess amounts are excreted.

• Rain and snow form around particles of dust in the air.

• The air in the earth's atmosphere circulates around the globe.

• The lifestyles of northern Alaska Natives have been changing. They have become more dependent on foods shipped in from elsewhere and rely less on subsistence hunting.

THE PUZZLE

Based on what you know about tundra ecology, the food chain, and the information given, **(a)** explain why higher concentrations of cesium-137 might be found in the tissues of humans and wolves who live in the arctic tundra than in the rain or soil of tundra. **(b)** Why do you think that the levels of cesium-137 in arctic people have declined in recent years?

Tundra Puzzler 2

IS TUNDRA RADIOACTIVE?

What Ecologists Have Learned

(a) Once released into the atmosphere, cesium-137 molecules are spread widely by air currents. These radioactive molecules settle back to earth, mainly in rain drops and snow flakes.

Because lichens get their minerals from rain and snowmelt water, and cesium-137 mimics potassium (a mineral they need), lichens rapidly take up and hold cesium-137 in their body tissues. Plants also take up and hold cesium-137, but at a slower rate than do lichens because they absorb water and minerals from the soil rather than directly from rain and snowmelt.

The soil itself traps and filters out some of the cesium-137, and some never reaches the soil as it flows away in run-off water. In addition, many plants die back and shed their leaves each winter. Most lichens, by contrast, hold the same tissues for years or even decades and thus may accumulate much of the cesium-137 they absorb.

During some winters, caribou eat mainly lichens. Their bodies respond to cesium-137 as they would react to potassium, by absorbing and holding it in their body tissues and fluids. The amount of cesium-137 held by a caribou depends on its diet and other factors.

When caribou feed mainly on contaminated lichens, they absorb and hold some of the cesium-137 that was originally taken up by the lichens. Humans and wolves who eat the caribou take up and hold the cesium-137 from the caribou tissue.

Humans and wolves who eat a lot of caribou that have fed upon heavily contaminated lichens can end up with surprisingly high levels of cesium-137 in their bodies.

In one study, scientists found concentrations of cesium-137 in lichens to be five times that found in rain and snow, and that in caribou four times greater than that in lichens. Humans and wolves had levels similar to or greater than those found in caribou.

It is important to note, however, that the retention of cesium-137 by lichens and other members of this food chain varies considerably. Cesium-137 is always transferred through lichen food chains, but concentration does not always occur.

The amount and rate of cesium-137 exchange through tundra food chains depend on many factors, including the amount of precipitation, the level of lichen contamination, the proportion of contaminated lichens in caribou diets (and what else is in their diet), plus the proportion of contaminated caribou and the kinds of other foods in the diet of the consumers of caribou.

(b) The level of cesium-137 in northern Alaska Natives has dropped because the amount of radioactive fallout has declined since atmospheric testing of nuclear weapons has become less common.

Also, Native people are eating more foods imported from elsewhere and fewer caribou, particularly in spring when concentrations of cesium-137 in caribou are highest (lichens are the main winter food of caribou).

Tundra Puzzler 3

HARD LIFE FOR ARCTIC BROWN BEARS

Background Information

The following information *approximates* the reproduction and **mortality** rates in a population of brown bears living in part of Alaska's arctic tundra. (*Actual mortality figures vary widely.*)

Female brown bears (grizzlies) in tundra areas do not begin producing young until they are eight years old, and then have one litter about every four years. Nearly all female bears have their last litter at about age 20, and die of old age after raising that litter.

In northern tundra areas, female bears give birth to two cubs per litter. On average, half of the cubs born are female.

Young bears have poor **survival rates**. About 40 percent of the cubs die before they are four years old.

For a bear population to remain stable or to grow, each female bear must produce at least one female young that survives to breed. This represents one female bear to replace her when she dies.

Bears four years and older usually have good survival rates. On average, only about 2 percent of these bears die each year from sources other than human-caused mortality. Most of these deaths are the result of accidents, disease, and fights among bears.

Because male bears fight more often than female bears, they have a higher death rate. Female bears five years and older outnumber adult male bears three to two.

The number of bears **harvested** by hunters is limited by regulations. Female bears with cubs cannot legally be killed unless in defense of life or property. Regulations allow people to harvest about 3 percent of the brown bears in a tundra population each year.

The combination of natural deaths and legal harvest of bears by humans means that about 20 percent of the adult females die every four years.

The number of bears killed in defense of life or property cannot be controlled by regulations. It can, however, be minimized by changes in human behavior. Brown bears are **omnivores** and are often attracted to garbage, dog food, birdseed, and campsites where food has been prepared. Changes in human behavior can lessen the frequency with which bears come in contact with people and their property.

In northern Alaska, 70 percent of the bears' natural diet is vegetation. They also feed on ground squirrels, marmots, bird eggs, and caribou and scavenge dead animals. They travel over **home ranges** from 60 to 700 square miles (155-1813 km^2) in search of adequate food supplies.

THE PUZZLE

Based on this background, **(a)** how many cubs could a single female brown bear living in an arctic tundra area produce in her lifetime, if she survived a full life span?
(b) How many of these would survive to age four?
(c) To breeding age (eight years)?
(d) What is the maximum number of female young that 100 female cubs could produce given the above mortality rates? *Calculate how many survive each four-year period of their lives to produce a litter of cubs, then multiply that number by the number of cubs produced. Divide by half to find out the number of females.*
(e) How many of these would survive to breeding age?
(f) Considering the given reproduction and mortality (death) rates, would the bear population remain stable, increase, or decrease?
(g) Imagine yourself as a bear biologist in the arctic with this information. Predict how increasing human populations and development may affect brown bear populations.

Tundra Puzzler 3

HARD LIFE FOR ARCTIC BROWN BEARS

What Ecologists Have Learned

Because of the slow reproductive rates of tundra brown bears, their populations grow slowly even under undisturbed circumstances.

In the example given,
(a) one female will produce eight cubs in her lifetime, four of which will be females.

(b) Only 2.6 of the females will survive four years.

(c) Only two will survive to breeding age.

(d) If you calculate the survival of the 100 female cubs born, you will find that 40 survive to four years,

(e) 32 to age eight (when they produce 32 female cubs); 27 to age 12, 22 to age 16, and 18 to age 20. By adding up the number of female cubs produced, (remembering that cubs are only produced every four years on average) you should find that 99 female cubs would be produced by each 100 female cubs born.

(f) This is just barely enough to keep the population stable.

(g) Because bears are wide-ranging and are attracted to human settlements, increasing human populations and development inevitably lead to more human-bear encounters. Because human-bear encounters often result in the bear being killed, the consequence of increasing human populations and development in tundra regions of Alaska is an increase in brown bear mortality.

A bear biologist who found the production and mortality rates given in the example would have to conclude that development could lead to a decline in brown bear populations.

BEAR OUTLOOK

Brown bears formerly ranged throughout the lower 48 states south to Mexico. Today, only two small populations remain in the lower 48 states – one in Yellowstone National Park and the other in the mountains around Glacier National Park.

Human development in bear habitat has been the main cause of brown bears disappearing from their formerly extensive range.

Today, harvest regulations help prevent humans from killing too many bears. As wild areas are developed, however, human-bear encounters increase and so does the number of bears killed by humans.

In tundra regions, where bear production is low and where individual bears must travel vast areas to find adequate food, scientists consider it very likely that increasing development will lead to bear population declines.

The information provided in the example is based on research by the Alaska Department of Fish and Game in northern Alaska. However, the actual reproduction and mortality rates of brown bear populations vary considerably from place to place and year to year. In other environments, reproduction rates are higher. Brown bear populations can withstand low levels of human harvest, but small increases in the number of bears killed can cause a population decline.

Tundra Puzzler 4

LICHENS, CARIBOU, AND ACID RAIN

Background Information

• **Lichens** are a symbiotic association of two kinds of living things. These include an **alga**, which **photosynthesizes** food, and a **fungus**, which provides a protective shell and helps absorb water and minerals from the environment. Lichens grow on soil, rocks, and wood.

• **Chlorophyll** molecules are found in leaves of plants and in **algae** cells. These molecules capture the sunlight energy used in photosynthesis.

• Lichens reproduce vegetatively. Vegetative reproduction does not occur on acidic surfaces or soils.

• Lichens obtain water and minerals primarily from rain and snowmelt water. They dry out in an absence of moisture, but soak up moisture like a sponge when it becomes available.

• Lichens live for many years and absorb air and waterborne particles much more quickly than do plants. This results in high concentrations of certain chemicals in their tissues.

• Lichens are an important winter food for caribou. The burning of fossil fuels (oil, gas, coal, and wood) releases a variety of chemicals into the air, including nitrogen dioxide, carbon dioxide, carbon monoxide, and sulfur dioxide.

• The atmosphere is made of several layers of air. The layers of air are constantly mixing and moving because of changes in air pressure, temperature, and moisture content. Large masses of air often travel thousands of miles over the earth's surface.

• Smoke from industries and power plants that burn fossil fuels often causes air pollution problems in nearby areas. These problems have been reduced by building very tall smoke stacks that send the smoke higher into the atmosphere where much of it is dispersed by winds and prevented from settling in nearby areas.

• When air pressure conditions are suitable, the water vapor in clouds condenses around particles and falls back to the earth as rain or snow. The precipitation carries the particles back to earth.

• The pH of soil, rocks, and wood is affected by the acidity of the precipitation.

• Many chemicals are soluble in water. That means they dissolve or become thoroughly mixed with water. The amount and kinds of chemicals dissolved in water determine the pH of the water. Concentrations of certain chemicals cause water to have a low pH – become **acidic.** These include sulfur dioxide and nitrogen dioxide. Other chemicals cause water to have a high pH – become **alkaline.**

• Sulfur dioxide and nitrogen dioxide – and compounds derived from these – change chlorophyll molecules so that they no longer function.

THE PUZZLE

Based on the given information and your knowledge of ecology, **(a)** explain how caribou populations of Alaska potentially could be affected by industrial development in Western Europe or Siberia. **(b)** What else might be affected?

Tundra Puzzler 4

LICHENS, CARIBOU AND ACID RAIN

What Ecologists Predict

The potential for air pollution in Western Europe or Siberia to affect caribou populations in Alaska is, at present, speculation. The potential effects are cause for concern, however.

(a) Sulfur dioxide and nitrogen dioxide are released by burning fossil fuels. As a result of air currents and movement in the upper atmosphere, these and other compounds can be carried thousands of miles from their place of origin.

When water vapor in clouds condenses and falls to earth as precipitation, it carries particles with it. Sulfur dioxide and nitrogen dioxide particles dissolve in water and make precipitation acidic.

Acid rain has been shown to be a problem in tundra regions of Norway and Sweden. It has not yet been documented as a problem in arctic Alaska, but many scientists are concerned that it will become a problem. Air currents in the Northern Hemisphere carry air from Western Europe and Siberia into arctic Alaska. Pollution from these sources is considered part of the cause of the arctic haze which has appeared in northern Alaska since the 1950s.

Local industrial development and increasing human populations may also contribute to air pollutions. About 110 gallons (416 liters) of fuel are burned every time a jet takes off. Thousands of gallons of fuel are burned each day by communities and the oil exploration and development industry for oil production and for daily use of vehicles, heating, and electric generators.

Acid rain has two serious consequences for lichens. (1) Sulfur dioxide and nitrogen dioxide – whether dissolved in water or in particle form – interfere with the functioning of the chlorophyll molecules in algae, thus preventing photosynthesis. Unable to make their own food, algae and the dependent fungi die. (2) Acid rain acidifies the substrates – soil, rocks, and wood – on which lichens grow. Because lichens are unable to grow on acidic surfaces, acid rain also can prevent lichen growth and establishment.

(b) Acid rain in tundra regions of Alaska could affect all life forms dependent on lichens also. Because lichens are a primary winter food for caribou, acid rain could cause declines in caribou populations. Consumers of caribou, including wolves, bears, and humans, would ultimately be affected.

Similarly, populations of other consumers of lichens, and populations of their predators, could be harmed. Lichens are important insulators of the permafrost and are used as nesting material by some birds.

Understanding the full story of lichens in the tundra is still in the preliminary stages. Lichens may have hundreds of other as-yet-unknown functions. Because of the complex web of interconnections in tundra ecosystems, many ecological changes may occur as a result of acid rain on lichens.

Examine the Issues

2 VARIATIONS and 1 EXTENSION

Section 5
TUNDRA ACTIVITIES

Grade Level: 4 - 12

State Standards: RI.8.2, RI.10.2

NGSS: 4-ESS3-1,5-ESS3-1., MS-LS2-1, MS-LS2-4.,MS-ESS3-4, S-LS2-7.

Subjects: Science, social studies, language arts

Skills: Research, evaluating, decision-making

Duration: Two sessions over several weeks, plus library research

Group Size: 1 or 2

Setting: Indoors

Objective:

Students will research a current issue concerning the Alaska tundra. They will compare their opinion on this issue before and after conducting the research.

Teaching Strategy:

Students research an issue about the Alaska tundra.

Materials:

Paper and pencil; magazines, newspaper, and other information about a selected issue; 2 signs with the words “Agree” and “Disagree.”

Background:

See *INSIGHTS, Section 5, Human Impacts: “Teacher’s Guide for Dealing with Differing Viewpoints.”*

Sample Issues:

A variety of issues exists relating to tundra areas of Alaska. Following are some suggestions for study:

- Exploration and development of oil and gas resources in the Arctic National Wildlife Refuge and National Petroleum Reserve – Alaska
- Disposal of trash (pop cans, plastic bags, batteries, machines)
- Using off-road vehicles on tundra
- Disposing of human wastes and dealing with water pollution in tundra towns, in villages, and at oil exploration camps
- Effects of the oil pipeline and the Prudhoe Bay development
- Evaluating toxic pollution and the health of the people and ecosystem of St. Lawrence Island
- Effects of dispersal of tropical pesticides in tundra regions by water and air currents
- Researching, restoring, and managing the Steller’s eiders, spectacled eiders, brant geese, or white-fronted geese
- Global warming, the “Greenhouse Effect,” and their effects on the tundra
- Lichens and acid rain

Procedure:

1. By reading through newspapers or by reviewing the list, students identify an issue that relates to their local area, or one in which they have a particular interest. Have students vote on the issue they are most interested in studying.

2. After selecting an issue, students write one sentence describing their opinion of how the issue should be resolved.

3. Place the "Agree" and "Disagree" signs on opposite sides of the room.

4. The teacher reads aloud each student statement of opinion (group similar ones). Students show their agreement or disagreement with each statement by standing near the "Agree" or "Disagree" sign. Record which opinions of the issue receive the most agreement and disagreement.

5. Students determine the individuals and groups likely to have an interest, or position, related to the issue. For example, who will be affected by the declining eiders? Stress that some people, or groups, may be involved in an issue even though students don't see a direct connection.

6. Students write a letter to each of the interested parties to request information about its position. While waiting for replies, students gather articles and relevant information. Students might also invite speakers to the class or interview individuals with an interest in or knowledge about the specific issue. *Stress the importance of obtaining and examining information and viewpoints from all sides of the issue.*

7. After sharing and evaluating the positions of all interested individuals and organizations, each student writes a sentence describing how she thinks the issue should be resolved.

8. Repeat the process of students demonstrating their agreement or disagreement with each resolution by standing under the appropriate sign.

9. Compare the statements that received the most agreement this time with those that received the most agreement before students researched the issue. Discuss why there is or is not a difference. Discuss the effects and consequences of negative and positive propaganda. How much are students' opinions influenced by their social, physical, and financial environments?

VARIATIONS

A. Some students may express themselves more creatively by using different formats. They may dramatize the assignment, write a play or reader's theater adaptation, create a photographic record, or build models.

B. Assign individuals or groups to role-play each of the interested parties. Then, hold a hearing on the topic.

Evaluation:

Students write an essay stating what they think is the best resolution of the issue and what they perceive as the positive and negative consequences of their resolution (for people and tundra ecosystems). Students should demonstrate an understanding that human activities can affect tundra ecosystems.

EXTENSION:

Conduct interviews and publish results. Students interview a Native elder or other long-time member of the community to determine community sentiment, the history or background of the issue, and its perceived impact on the environment and on the culture.

As a class, read Cook Inlet Region's *Tips on Interviewing* and discuss appropriate and inappropriate ways to approach an interview situation. Stress that questions must be relevant and sensitive to the individual and to local cultural values.

Divide the class into small groups to conduct mock interviews. Students should have a list of questions they would like to ask and the rationale for each question. They should discuss "what-if" situations. For example, what should be done if the interviewee feels uncomfortable with the topic or strays too far away from the subject?

How will students publish their final product? *Our Stories, Our Lives* and *Growing Up Native in Alaska*, both by A.J. McClanahan are excellent compilations of local histories. Students might write and illustrate a group book.

Groups may wish to compare their results. What have they learned as a result of this exercise – how can they extend it? Perhaps a letter to the editor of the local newspaper is appropriate. Do they have a chance for community involvement?

A follow-up and thank-you letter to the interviewee is certainly appropriate.

Curriculum Connections:

(See appendix for full citations)

Books:

The Arctic (Rootes)

Arctic & Antarctic (Weller)

Arctic National Wildlife Refuge (Siy)

Facts on File Environment Atlas (Wright)

Food Chains (Silverstein)

Growing Up Native in Alaska (McClanahan)

Hazy Skies: Weather and the Environment (Kahl)

Into Thin Air: the Problem of Air Pollution (Kidd), 7-12

Kid's Guide to Social Action (Lewis)

Never Cry Wolf (Mowat), 10-12

Our Stories, Our Lives (McClanahan)

Vanishing Ozone: Protecting Earth from Ultraviolet Radiation (Pringle)

Who Really Killed Cock Robin? An Ecological Mystery (George)

Video:

Arctic Refuge: A Vanishing Wilderness (National Audubon Society)

Websites:

Alaska Department of Fish and Game <www.adfg.alaska.gov>

Alaska Natural History Program <www.alaska.uaa.edu/enri/aknhp_web>

Alaska Statewide Databases <sled.alaska.edu>

Arctic Circle studies <arcticcircle.uconn.edu> link to "Natural Resources"

Arctic National Wildlife Refuge <arctic.fws.gov>

Arctic National Wildlife Refuge: A Special Report available on <arcticcircle.uconn.edu/ArcticCircle/ANWR> (presents divergent viewpoints)

Arctic Power <www.anwr.org> (development angle)

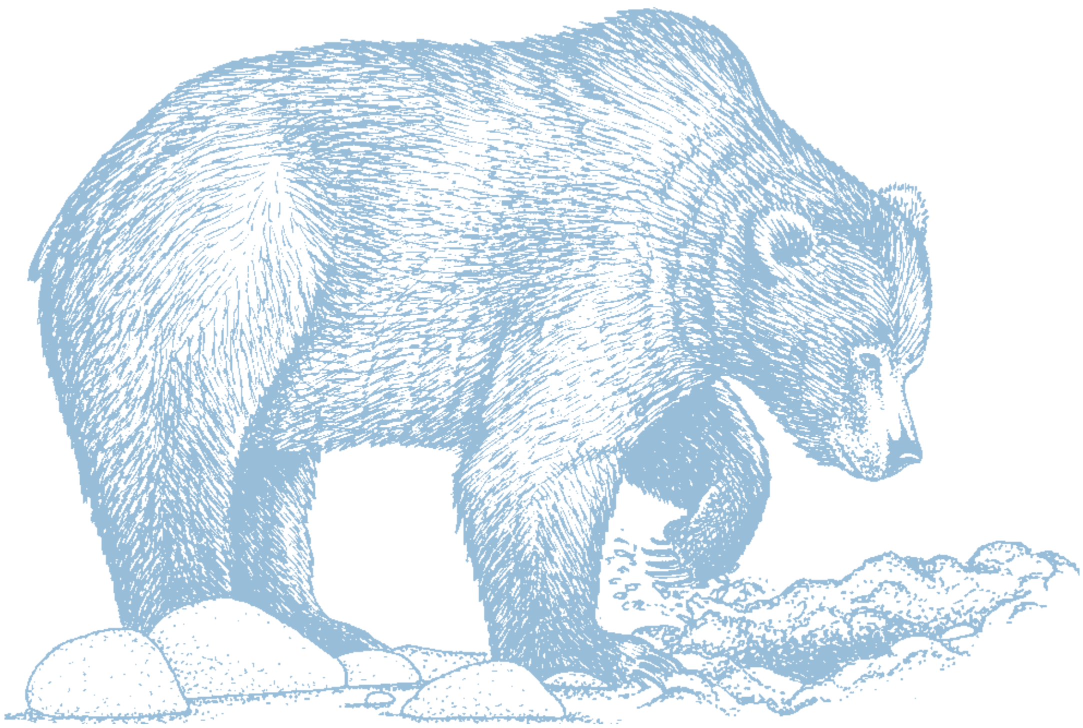
Staff-written Alaska newspaper articles: *Anchorage Daily News* Archives <www.adnsearch.com> or *Fairbanks Daily News Miner* <www.newsminer.com>

U.S. Fish & Wildlife Service - Alaska <www.r7.fws.gov>

USGS – Alaska Biological Science Center website <www.absc.usgs.gov>

Teacher Resources:

(See appendix)



TUNDRA APPENDICES

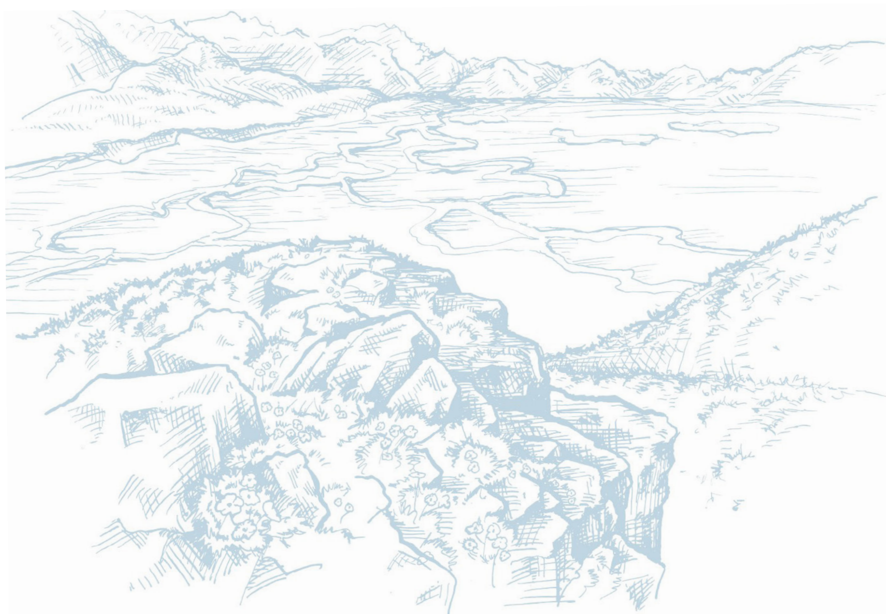
GLOSSARY

TEACHER RESOURCES
(General and Section Specific)

FULL CITATIONS – ACTIVITY CURRICULUM CONNECTIONS

MORE CURRICULUM CONNECTIONS
(Folktales, Fiction, Poetry, Biographies, and Picture Books)

PLANNING TOOLS
(Activities cross-referenced by grade, topic, activity, state standards)



GLOSSARY

Acid: a chemical with a pH value less than seven

Acid rain: rain that has a high concentration of nitric and sulfuric acids from pollution or natural sources

Acidic: acid forming

Active layer: the layer of soil lying on top of permafrost that thaws and refreezes each year

Adaptation: (a-dap-TAY-shun) the process of adjusting to the environment; a trait that helps an organism survive in a particular environment

Air: the mixture of invisible, odorless, tasteless gases that surrounds the earth

Algae: (AL-jee) a large group of primitive plants having chlorophyll, but lacking true roots, flowers, stems, and leaves (singular: alga)

Alkaline: (AL-kah-line) having a pH value greater than 7; also called a **base** *(see entry)*

Alpine tundra: cold, windy, treeless environments occurring at high elevations above tree line throughout the world

Angle of incidence: angle that a ray of light striking a surface forms with a line perpendicular to that surface

Arctic haze: a reddish-brown layer of air pollution from industrialized areas of the northern continents that accumulates in the arctic air during winter because there is little rain or snowfall to remove pollutant particles

Arctic tundra: the cold, windy, treeless environment found in the arctic and maritime subarctic; also called high-latitude tundra and lowland tundra; distinguishable from the alpine tundra

Atmosphere: the whole mass of air surrounding the earth

Axis: a real or imaginary straight line passing through an object or body, such as the earth, and around which the body rotates or seems to rotate

Bag limit: term used in wildlife management; the maximum number of animals of any one species that a person may legally kill in one area

Base: a chemical that has a bitter taste, turns litmus paper blue, reacts with an acid to form a salt, and has a pH value greater than seven

Biome: major plant communities and their living organisms around the world; examples include tundra, tropical rain forest, taiga, temperate deciduous forest, grassland, or desert

Blubber: the fat of whales and other large marine mammals

Burrow: (BUR-oh) a hole in the ground made and used by an animal

Calf: newborn or young caribou

Calving ground: area where female caribou traditionally come to give birth to their calves in late May and early June (caribou herds are identified by the area where they calve because that is distinctive to each herd)

Carnivore: (KAHR-neh-vohr) an organism that eats other organisms (The majority are animals, but a few fungi, plants, and protists are also carnivores.)

Chlorophyll: (KLOHR-uh-fil) a group of pigments that produces the green color of plants; essential to photosynthesis

Climate: the average conditions of the weather *(temperature, wind velocity, precipitation, sunlight)* at a location over many years

Cold: absence of heat; something that has a temperature that is lower than the surrounding area

Colonization: (kah-luh-nigh-ZAY-shun) when animals or plants become established in a new territory that they had not previously inhabited

Commensalism: (kuh-MEN-sah-li-zum) an interaction between two kinds of living things from which one species benefits and the other is unaffected; a form of symbiosis

Community: all the living things that interact in a common location

Compacted: (KOM-pak-tid) in soils and snow, when pressure from above ground has compressed or eliminated the air spaces between underlying particles

Compaction: (kom-PAK-shun) the process in which the air spaces between underlying particles are compressed or eliminated

Conductor: (kon-DUK-tore) a material that transmits heat energy

Constructive snow metamorphism: natural changes in the layers of snow as new snow falls or as temperatures increase or decrease

Consumer: (kon-SOO-muhr) any living thing that must consume (eat) other organisms, living or dead, to satisfy its energy needs

Corrode: (kah-ROHD) to wear away, especially by oxidation (as in rust) or other chemical action

Cover: protection from the elements for many purposes, including hiding, traveling, resting, and nesting; also referred to as **shelter**; one of the four elements necessary for survival

Crustose: (KROOS-toes) describes lichens whose leaf-like structures are thin and crusty and that grow very close or attached to a surface

Decomposer: (dee-kom-POHZ-er) an organism that breaks down organic (living or formerly living) material (All consumers fit this category, but the word is sometimes used to refer to **detritivores** only *[see entry[*.)

Decomposition: (dee-kom-poh-ZI-shun) an act of breaking or separating into basic components or parts

Desiccate: to dry

Defense: the act of defending against attack, danger, or injury; a means or method of defending or protecting

Density: (DEN-si-tee) the average number of individuals within a certain space unit

Depth hoar: the layer of large, cup-shaped crystals near the ground in the snow pack

Detritivore: (de-TRI-tuh-vohr) an organism that obtains it energy needs by consuming (eating) wastes and other living things that have died (See also **decomposer** and **scavenger**.*)*

Detritus: (de-TRI-tes) organic waste material such as dead or partially decayed plants and animals or excrement; an important source of nutrients in a food web (Detritus can also be small particles of minerals such as sand or silt.)

Domestic: animals that are tamed, captive, or bred by humans

Dormant: a period of suspended growth and metabolic activity (Many plants, seeds, spores, and some invertebrates become *dormant* during unfavorable conditions.)

Drawing permit: used in wildlife management; a permit drawn in a lottery that allows an individual to participate in a specific hunt

Ecology: the study of the interrelationships among living things and between living things and their nonliving surroundings

Ecosystem: (EH-coh-sis-tem) a community of living things and their nonliving surroundings linked together by exchange of energy and nutrients

Enchytraeids: (en-ki-tree-aids) a group of segmented worms that live in the soil

Environment: the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival

Extirpate: to cause localized extinction of a living thing, removing its population from a region (Muskoxen were *extirpated* from Alaska in about 1865, but they still survived in Greenland.)

Foliose: describes lichens whose leaf-like structures are divided into many lobes

Food: energy and minerals in a form living things can use

Food chain: the transfer of food energy from living things in one nutritional level to those in another (In a simple *food chain*, for example, a mammal eats a bird that ate an insect that ate a plant.)

Food web: many interconnecting food chains

Forest: any ecosystem that contains many trees

Freezing point: temperature at which a substance freezes and becomes a solid

Frost boil: tundra landscape feature; a small rise caused by the expansion of underlying ice; found in areas underlain by ice or permafrost

Fruticose: (FRUI-tee-koes) describes lichens that grow in the form of tiny shrubs

Fungus: a living thing from the kingdom Fungi that includes mushrooms, yeasts, molds, fungi, lichens, and slime molds; all are detritivores characterized by their cell structure; plural: fungi (FUN-jee)

Gas: a compound that characteristically has no fixed shape or size (Gases will fill and take the shape of any container.)

Habitat: the place where something lives and that provides the food, water, shelter (cover), and space that the organism needs to survive

Half-life: the period of time required for half of a quantity of a radioactive isotope to be eliminated or disintegrated by natural processes

Harvest: the act or process of gathering a crop or animals (In wildlife management, hunting is considered a form of harvest in which individual animals are killed.)

Heat energy: another term for heat

Heliotropic: (HEE-lee-tro-pik) growth or orientation of a immobile organism, especially a plant, toward the light of the sun

Herbivore: a living thing that eats producers such as plants, algae, or lichens

Herd: group of animals that stay or come together annually

Hibernate: to spend the winter in an inactive state during which life processes (breathing, heart rate, body temperature, etc.) are reduced but not shut down

High-elevation tundra: another term for alpine tundra; refers to cold, windy, treeless environments occurring at high elevations throughout the world

High-latitude tundra: another term for lowland or arctic tundra; refers to the cold, windy, treeless environment found in the arctic and subarctic

High-center polygon: a landform on the tundra (or in the taiga) that has been uplifted to form a many-sided pattern on the ground (Polygons are formed by ice wedges and permafrost.)

Home range: an area that an animal or family group occupies on a daily or seasonal basis in search of food (The home range does not necessarily correspond to territory, which is the area defended by an animal or a group.)

Host: an organism that serves as the habitat for a parasite

Hunting season: in wildlife management, a period of days or months that defines the legal hunting time for a type of animal in a particular region

Hypotheses: (hi-PAH-thah-sees) tentative explanations that account for a set of facts and can be tested by further examination; something taken to be true for the purpose of argument or investigation; an assumption (If a *hypothesis* withstands experimental tests, it may be elevated to a theory.)

Ice wedge: a crack in the ground that expands each winter with the freezing of melt water that seeped into the crack during summer

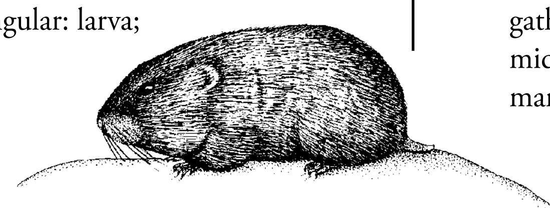
Insulating ability: the capability of a material to reduce the movement of heat energy

Insulation: anything that reduces the movement of heat energy into or out of a particular object or area

Insulator: material that slows down the movement of heat energy

Invertebrate: (in-VER-tuh-brate) an animal without a backbone or internal bony skeleton; includes insects, crustaceans, worms, corals, and mollusks

Larval stage: the immature form of a living thing that undergoes metamorphosis (Tadpoles, grubs, and caterpillars are all in the larval stage that is radically different from the adult frogs, beetles, and butterflies that they become after metamorphosis. Singular: larva; plural: larvae.)



Latitude: distance of a given point on earth north or south of the equator

Lemming: small arctic rodent (Lemmings resemble mice but have short tails

and fur-covered feet.)

Lichen: plantlike organism that consists of a fungus and an alga existing together to the mutual benefit of each (Lichens are pioneer plants that help create soil for others. Because of their sensitivity to air pollution, they are useful as indicators of air quality.)

Limiting factor: something that keeps a population of animals or other organisms from increasing (It could be a shortage of food, water, shelter, or space. Or it could be disease, predation, climatic conditions, pollution, hunting, poaching, or accidents that affect either the number of births, of deaths, or of both.)

Liquid: a state of matter in which the atoms or molecules are not fixed rigidly in position relative to each other, as they are in a solid, but they do not move around quite as independently as they do in a gas

Low-center polygon: a tundra or taiga landform; a surface depression with uplifted, many-sided edges on the ground (Polygons are formed by ice wedges and permafrost.)

Lowland tundra: the cold, windy, treeless environment found in the arctic and maritime subarctic; also called arctic or high-latitude tundra

Metamorphosis: a process of developmental change in insects where a *larva* reaches adulthood only after a radical change in form, often involving a pupa stage

Midges: (mid-jes) any of various tiny flies that often gather in large swarms in cool, damp areas (Some midges can inflict a painful bite. Midge larvae, like many fly larvae, are detritivores.)

Migration: a regular, seasonal movement of an animal from one place on earth to another

Molt: the shedding of old feathers or hair to be replaced with new; usually yearly

Monerans: (mo-NERR-ans) one of the five kingdoms of living things, including microscopic bacteria and blue-green algae (Monerans do not have a cell nucleus.)

Mortality rate: the number of deaths in a given time or place; the proportion of deaths to the total population

Mutualism: (MYU-chuh-wah-li-zam) a relationship between organisms in which all benefit; a type of symbiosis

Nomadic: roaming about from place to place

Nonliving: something that does not, and cannot, move, grow, or make new things like itself (Air, water, soil and rocks, and energy are the nonliving things found in all ecosystems.)

Nonliving environment: all of the external influences that do not involve living things; for example, rainfall, soil type, temperature, and sunlight

North pole: northernmost point on the earth; the northern end of the earth's axis

Nutrient: any element or simple compound necessary for the health and survival of an organism; includes air and water as well as food

Omnivore: (AHM-nee-vor) a living thing that eats both producers and other consumers

Parasitism: (PAIR-uh-si-ti-zam) a kind of symbiosis; an interaction where an organism lives on or within another organism on which it feeds (The parasite benefits and the other, the *host*, is harmed.)

Peat: moist, semi-decayed organic matter

Peat bog: a poorly drained wetland area with acidic spongy ground and made of dead but largely undecayed peat – sphagnum moss and other vegetable matter

Percolate: (PER-ko-late) to filter or trickle through a porous substance; for example, the gravity flow of water or liquid down through soil or rock

Periodic: recurring at regular intervals; can refer to seasonal cycles or daily cycles

Periodic cold: the change in temperature between night and day that occurs especially at high elevations

Permafrost: soil that is 32°F (0°C) or less all year round (It may or may not contain ice. In the arctic tundra, permafrost may extend anywhere from a few feet to more than 1000 feet below the surface.)

Permit: in wildlife management, an authorization to harvest or view wildlife in a selected area

Persistent winds: enduring or continuous windy conditions

Photosynthesis: (fo-to-SIN-tha-sis) the way that sunlight energy is absorbed by chlorophyll and is used to fuel the building of sugar molecules in plants and algae

Pika: a small mammal of the genus *Ochotona* that resembles a rabbit with a short tail, rounded ears, and two pairs of upper incisors; usually live in rocky areas at high altitudes

Pingo: a tundra landform; an ice-filled hill on the tundra, sometimes 230 feet (70 meters) or more high and 2000 feet (610 meters) in diameter; it may be circular, oval, or irregular in form; usually covered with vegetation on the south side

Poaching: the act of hunting or fishing illegally

Population: a group of individuals of the same species occupying a given area at the same time

Predator: an animal that kills and eats other animals

Predict: to declare beforehand, based on experience, observation, or scientific reason

Prey: animals that are killed and eaten by other animals

Producer: any living thing that can convert nonliving materials (air, water, soil, and light) into food for itself and other living things (Plants and algae are examples of producers.)

Pupa: in metamorphosing insects, a stage between the *larva* and adult (The pupa may appear to be inactive, but inside its protective cases, it undergoes metamorphosis from the larval stage into the adult form. Plural: pupae.)

Radioactive isotope: a chemical element with the same atomic number and identity as another element but with a different atomic weight (Radioactive isotopes tend to disintegrate and emit particles and waves that can be altered by x-rays. These particles often give scientists evidence about the age of substances.)

Revolution: the journey that the earth takes around the sun (One revolution is 365 days, and has four seasons.)

Rhizomes: (RI-zome) horizontal underground stems of plants that send up leafy shoots from the upper surface of stem and send down roots from the lower surface; an adaptation for plant reproduction in cold climates

Rotation: the spinning or turning of the earth on its axis (The earth rotates once every 24 hours.)

Rut: refers to the season in which male ungulates (deer, moose, caribou, muskox, sheep, goats, and elk) perform mating behaviors, including shows of strength against other males and attentiveness toward females (The sound of two males' antlers or horns clashing together is a common sign that these animals are in rut.)

Salinity: (suh-LIN-i-tee) the degree of saltiness

Scree: loose rock debris covering a slope

Shelter: protection from the elements for many purposes, including hiding, traveling, resting, and nesting; also referred to as **cover**; one of the four elements all animals need to survive

Slumping: the downward movement of soil

Snow crystals: formed when a piece of dirt, a particle of dust, or a bit of airborne pollution draws water vapor molecules from a surrounding cloud (Temperature and available moisture determine the snow crystal's shape, size, and elaborateness.)

Soil formation: the making and mixing of small particles of inorganic minerals and organic (formerly living) particles to form the layer of material on the surface of the earth that is the natural medium for plant growth

Solar energy: heat and light from the sun

Solid: a material in which the atoms are held in definite positions relative to one another (This means that the material is rigid; it resists if it is pushed into different shapes and does not flow like a fluid to fill a container.)

Solifluction/gelifluction: (SOE-luh-fluk-shun) a type of slow landslide in which the waterlogged layer of soil that covers permafrost slides downhill on a slope

South pole: the southernmost point of the earth; the southern end of the earth's axis

Specific tolerances: the range of environmental factors such as salinity, moisture, or heat that an organism can tolerate

Springtail: any various small, wingless insects of the order *Collembola*, having abdominal appendages that act as springs to catapult them through the air (Springtails are detritivores.)

Sublimation: (suh-bluh-MAY-shun) in snow, the change of snow crystals to water vapor without first becoming liquid water

Subnivean: (sub-NIV-ee-an) refers to the insulated environment at the bottom of fallen snow layers, usually above the ground

Survival rates: the proportion of a population of living things that reaches a particular age (usually the age of reproductive capability)

Symbiosis: (sim-be-OH-sis) living together; an interdependence between two kinds of living things that live in close association; plural: symbioses

Taiga: the sparse forests of stunted trees near the edge of the tree limit; Russian for *land of little sticks*

Talik: (TAY-lick) layers and pockets of unfrozen soil that occur within permafrost soil

Temperature: the degree of hotness or coldness as registered by a thermometer

Temperature gradient: in fallen snow, the variation of temperature at the bottom of the snow pack (warmer) to the snow at the top

Thermokarst: a tundra landform; a surface depression created when permafrost in water-filled soil melts

Tilt: the relationship of the earth's axis to the sun (The earth's axis is placed at a 23.5-degree angle.

Tree line: the upper limit of tree growth in mountains or high latitudes because of unsuitable environment above; also called timberline

Tundra: the windy, treeless, and periodically cold environments that occur at high latitudes and at high elevations

Tussock: a small mound formed by certain tundra grasses that continually retain their dead leaves

Uncompacted: snow or soil that has not been trampled or packed by the weight of vehicles, objects, people, and other animals (Uncompacted snow tends to have more air between snow crystals than does compacted snow.)

Vertebrate: an animal with a backbone (Humans, birds, fish, and bears are examples of vertebrates.)

Warm: maintaining or preserving heat

Wetlands: an area that is regularly wet or flooded during part of the year and has plants that prefer wet soil

Wild: animals that provide their own food, water, shelter, and other needs; non-domesticated

Wind-chill: a still-air temperature that would have the same effect on exposed human skin as a given combination of temperature and wind speed

TEACHER RESOURCES

Most useful resources for teaching general and specific activities in *Alaska's Tundra and Wildlife*

Useful for All

Books and Publications:

Alaska Ecology Cards – Alaska Wildlife Curriculum. Alaska Department of Fish and Game, 2000.

Alaska in Maps: A Thematic Atlas. Fairbanks: University of Alaska, Fairbanks, 1998.

Alaska Northwest Books. *The Alaska Almanac: Facts About Alaska*. Anchorage, published annually.

Alaska Wildlife Notebook Series. Alaska Department of Fish and Game. Available to download on line <www.alaska.state.us/adfg> or from Wildlife Education, ADF&G, 333 Raspberry Rd., Anchorage, AK 99518.

Brune, Jeff and others. "Alaska's Cold Desert." *Science and Children Magazine*, May 1996. Reprinted on the website <www.blm.gov/education/arctic/arctic.html>

Davis, Neil. *Science Nuggets.* Fairbanks: Geophysical Institute, University of Alaska, Fairbanks. Reprinted 1999.

Ewing, Susan. *The Great Alaska Nature Factbook: A Guide to the State's Remarkable Animal, Plants, and Natural Features.* Anchorage: Alaska Northwest Books, 1996.

Junior Environment on File. New York: Facts on File, 1996.

Lingelbach, J. *Hands-On-Nature Information and Activities for Exploring the Environment with Children.* Woodstock, VT: Vermont Institute of Natural Science, 1986. Available <www.vinsweb.org>

Lynch, Wayne. *A is for Arctic*. Willowdale, Ont: Firefly Books, 1996.

Mateer, C.F. and L. Craft. *Let's Go to the Arctic*. Pittsburgh, PA: Carnegie Museum of Natural History, 1993. Available <www.clpgh.org/cmnh/doe/publications/kidbooks.html>

Pielou, E.C. *A Naturalist's Guide to the Arctic*. Chicago IL: The University of Chicago Press, 1994.

Williams, Terry Tempest, and Ted Major. *The Secret Language of Snow.* New York: Sierra Club/Pantheon, 1984.

Zwinger, Ann, and Beatrice Willard. *Land Above the Trees: A Guide to American Alpine Tundra*. Boulder: Johnson Books, 1996.

Websites:

Alaska Department of Fish and Game <www.adfg.alaska.gov>

Alaska Native Knowledge Network <www.ankn.uaf.edu> *Alaska Standards for Culturally Responsive Schools* and *Guidelines for Preparing Culturally Responsive Teachers for Alaska's Schools* are available on line. Ordering information for *Curriculum Resources for the Alaskan Environment* and *Inuuqatigiit* (curriculum from the Inuit perspective) are also available.

Alaska Natural Heritage Program <www.uaa.alaska.edu/enri/aknhp_web> Current status of Alaska's biodiversity, annotated species at risk project, and excellent links to Alaska biodiversity and biology resources.

Alaska Science Forum <www.gi.alaska.edu/ScienceForum> Treasure of new and archive articles written for general audiences answering science questions and highlighting Alaska's natural science phenomena and research

Alaska Statewide Databases, accessed through your local library website or <sled.alaska.edu> Magazine and newspaper articles from more than 2000 magazines and journals and 100 newspapers plus other information

Anchorage Daily News. Location of articles can be done with no charge. To get full text, a fee must be paid. Available <www.adnsearch.com>

Audubon On Line Field Guides. <www.enature.com> Has on-line field guides and habitat information

CRREL (Cold Regions Research and Engineering Laboratory) Virtual Library. <www.crrel.usace.army.mil/library> Has web links to arctic information

Fairbanks Daily News Miner. <www.newsminer.com> Staff-written newspaper articles, current and past, available on file, no fee

Project WILD <www.projectwild.org> Environmental education curriculum K-12 of the Western Regional Environmental Education Council; supported locally by the Alaska Department of Fish and Game

Smithsonian Museum of Natural History Arctic Studies Program. <www.mnh.si.edu/arctic/html> Dedicated to the study of Arctic peoples, cultures, and environments; virtual exhibits, wildlife features

U.S. Fish & Wildlife Service. Information on the Arctic National Wildlife Refuge. <www.arctic.fws.gov>

Section 1: Elements that Create Tundra

Books:

*Diagram Group. *Nature Projects On File*. New York: Facts on File, 1992.

*Farndon, John. *How the Earth Works: 101 Ways Parents and Kids Can Share the Secrets of the Earth.* Pleasantville, NY: Reader's Digest Association, 1992.

**Hands on Science Grades 1-2* and *Hands on Science Grades 3-4.* Greensboro, NC: Carson-Dellosa Publishing Co., 1991.

**Investigating Science-Planets and Space*. Huntington Beach, CA: Creative Teaching Press, 1987.

*Kim, Hy. *Showy Science.* Glenview, IL: Scott Foresman, 1994.

National Audubon Society. *Alaska Tundra, Arctic Wilderness [Poster*]. Address: Audubon Adventures, National Audubon Society, 613 Riversville Rd, Greenwich, CT, 06831 *or* <www.audubon.org/educate/aa/order.html>

National Geographic Society. *Atlas of the World.* Washington, D.C., 1999. (or any other world atlas)

*VanCleave, Janice. *Janice VanCleave's Earth Science for Every Kid: 101 Easy Experiments that Really Work.* New York: J. Wiley, 1991.

*Zike, Dinah. *The Earth Book; Activities for Kids.* New York: John Wiley, 1993.

* Books with lessons or hands-on experiments to teach what makes day and night, seasons, and the earth's rotation of the earth.

Websites:

Biome websites: Several are available on the Internet using a search for *"Biome."*

Section 2: Tundra Topography and Soil

CRREL Permafrost Tunnel north of Fairbanks is jointly maintained by the U.S. Army Cold Regions Research and Engineering Laboratory, the University of Alaska, and the Bureau of Mines. The tunnel is not open to the general public, but with prior arrangements, teachers and high school-age students can tour. Contact Department Chair, Mining Department, University of Alaska, Fairbanks, (907) 474-7388.

U.S. Geological Survey sometimes provides information or speakers. Address: USGS, Branch of Alaskan Geology, 4230 University Dr., Anchorage, AK 99508 *or* (907) 786-7495.

Section 3: Life Forms and their Tundra Adaptations

Books:

Alaska Wild Berry Guide and Cookbook. Anchorage: Alaska Northwest Books, 1982.

Armstrong, Robert. *Guide to the Birds of Alaska.* Anchorage: Alaska Northwest Books, 1995.

Borror, Donald. *Peterson's Field Guide to Insects.* Boston: Houghton Mifflin, 1998.

National Wildlife Federation. *Ranger Rick's NatureScope: Incredible Insects*. Niwot, CO: Robert Rinehart Pub., 1998.

Pratt, Verna E. *Field Guide To Alaskan Wildflowers.* Anchorage: Alaskakrafts, 1989.

Schofield, Janice. *Discovering Wild Plants: Alaska, Western Canada, the Northwest*. Anchorage: Alaska Northwest Books, 1989.

Viereck, Leslie, and Elbert L. Little, Jr. *Alaska Trees and Shrubs.* Fairbanks: University of Alaska Press, 1986.

White, Helen (ed.). *Alaska-Yukon Wildflowers Guide*. Anchorage: Alaska Northwest Books, 1989.

Section 4: Tundra Ecosystem-Community Connections

The Arctic Biology Institute's Large-Animal Research facility has educational tours in the summer and winter when prior arrangements have been made. Guided tours are available five times a day, June through August. Contact Institute of Arctic Biology Institute, P.O. Box 757000, Fairbanks, AK 99775-7000 *or* <www.uaf.edu/lars/index.html>.

Lemming mounts are included in Tundra Kits, which are available to some schools from the Alaska Science Center, Alaska Pacific University, 4101 University Dr., Anchorage AK 99508. Kits are available for $10 local users fee, or a $20 user fee plus return postage cost for nonlocal users. For further information <www.alaskapacific.edu/science>

The Muskox Farm in Palmer gives tours from May through late September; winter by appointment only. Contact Muskox Farm, P.O. Box 587, Palmer, AK 99665 *or* (907) 745-4151 *or* <www.muskoxfarm.org>. Located at Mile 50.1 of the Glenn Highway.

Section 5: Human Impacts on Tundra Ecosystems

Books:

Cook Inlet Region, Inc. *Tips on Interviewing*. Anchorage: CIRI Foundation, 2000. (907) 263-5582.

Lewis, Barbara. *Kid's Guide to Social Action*. Minneapolis: Free Spirit Publishing, 1998.

McClanahan, A.J. *Our Stories, Our Lives: A Collection of Twenty-three Transcribed Interviews with Elders of the Cook Inlet Region*. Anchorage: CIRI Foundation, 1986.

McClanahan, Alexandra. J. *Growing Up Native in Alaska*. Anchorage: CIRI Foundation, 2000. (biographies)

Wright, David R. *Facts on File Environment Atlas.* New York: Facts on File, 1997.

Moses, S. *Changing Waste in Changing Times: Solid Waste and Natural Resources Issues in Rural Alaska: A Teacher's Guide*. Seattle: Northwest Renewable Resources, 1994. Address: Northwest Renewable Resources Center, 1411 Fourth Ave., Suite 1510, Seattle, WA. 98101-2216 *or call* (202)-623-7361. (Gr. 9-12)

Media:

Acid Rain (video). Bala Cynwyd, PA: Schlessinger Video Productions, 1993. (Gr. 5-12)

National Audubon Society Specials. *Arctic Refuge: A Vanishing Wilderness.* (video) PBS. Available from <shop2.pbs.org/pbsvideo/pbsvideo.asp>.

Websites:

Arctic Circle studies <arcticcircle.uconn.edu> Of particular interest are the items under the heading "Natural Resources."

Arctic National Wildlife Refuge: A Special Report. Available on the website <arcticcircle.uconn.edu/ArcticCircle/ANWR> Presents both viewpoints on the development of the Arctic National Wildlife Refuge.

Arctic Power <www.anwr.org> dedicated to the development of the Arctic National Wildlife Refuge.

World Resources Institute <www.wri.org> Information, ideas, and solutions to global environmental problem

FULL CITATIONS – ACTIVITY CURRICULUM CONNECTIONS

Books and Publications

Alaska Department of Fish and Game. *Alaska Wildlife Notebook Series.*Onnline <www.adfg.alaska.gov>.

Alaska Geographic Society. *Mammals of Alaska.* Anchorage, 1996.

Alaska Geographic Society. *Moose, Caribou and Musk Ox.* Anchorage, 1997.

Alaska in Maps: A Thematic Atlas. Fairbanks: University of Alaska Fairbanks, 1998.

Alaska Magazine. *Alaska Wild Berry Guide and Cookbook.* Anchorage: Alaska Northwest Books, 1982.

Aldes, Rodney. *Polar Lands.* New York: Dillon, 1992.

Allaby, Michael. *Biomes of the World*. Danbury, CT: Grolier Educational, 1999.

Armstrong, Robert. *Guide to the Birds of Alaska.* Anchorage: Alaska Northwest Books, 1995.

Bancroft, Henrietta. *Animals in Winter.* New York: HarperCollins, 1997. (Gr. K-3)

Borror, Donald. *Peterson's Field Guide to Insects.* Boston: Houghton Mifflin, 1998.

Branley, Franklyn. *Sunshine Makes the Season.* Madison, WI: Demco, 1985.

Branley, Franklyn. *What Makes Day and Night*. New York: HarperCollins, 1986.

Brimmer, Larry. *Polar Mammals.* New York: Children's Press, 1996.

Byles, Monica. *Life in the Polar Lands*. Chicago: World Book, 1997.

Cobb, Vicki. *This Place Is Cold*. New York: Walker, 1989.

Cole, Joanna. *Scholastic's The Magic School Bus in the Arctic: A Book About Heat.* New York: Scholastic, 1998. (Gr. K-3)

Cooper, Ann. *Above the Treeline.* Denver: Denver Museum of Natural History Press, 1996.

Darling, Kathy. *Arctic Babies.* New York: Walker, 1996. (Gr. K-3)

DK Science Encyclopedia. New York: Dorling Kindersley, 1998. Also available in CD format. (contains information on seasons, what makes day and night, and the earth's rotation and revolution)

Edmonds, Alex. *Acid Rain.* Brookfield, CN: Cooper Beech Books, 1997.

Fardon, John. *How the Earth Works.* Pleasantville, N.Y.: Reader's Digest Association, 1992. (contains information on seasons and what makes day and night)

Forman, Michael. *Arctic Tundra*. New York: Children's Press, 1997.

Fowler, Alan. *Arctic Tundra: Land with No Trees.* New York: Children's Press, 1996.

George, Jean Craighead. *Julie of the Wolves*. New York: HarperCollins, 1972.

George, Jean Craighead. *One Day in the Alpine Tundra.* New York: HarperCollins, 1984.

George, Jean Craighead. *The Case of the Missing Cutthroats.* New York: HarperCollins, 1995.

George, Jean Craighead. *Who Really Killed Cock Robin? An Ecological Mystery*. New York: HarperCollins, 1991.

Gibbons, Gail. *The Reasons for Seasons.* New York: Holiday House, 1995.

Hirschi, Ron. *One Day on Pika's Peak*. New York: Dodd, 1986.

Houston, Pam. *Women on Hunting.* Hopewell, NJ: The Ecco Press, 1995.

Hoyt-Goldsmith, Diane. *Arctic Hunter*. New York: Holiday House, 1992.

Jones, Tim. *More Wild Critters.* Portland: Graphic Arts Center Pub. Co., 1994. (Gr. K-3)

Jones, Tim. *Wild Critters.* Portland: Graphic Arts Center Pub. Co., 1993. (Gr. K-3)

Kahl, Jonathan. *Hazy Skies: Weather and the Environment.* Minneapolis: Lerner, 1998.

Kalman, Bobbie. *Arctic Animals*. New York: Crabtree Publishing, 1988.

Kalman, Bobbie. *The Arctic Land*. New York: Crabtree Publishing, 1988

Kalman, Bobbie, and Jacqueline Langille. *What are Food Chains and Webs?* New York: Crabtree Publishing, 1998.

Kalman, Bobbie. *What is a Biome?* New York: Crabtree Publishing, 1998.

Kaplan, Elizabeth. *Tundra.* New York: Benchmark Books, 1996.

Kerasote, Ted. *Bloodties: Nature, Culture, and the Hunt.* New York: Kodansha America, 1993.

Kidd, J.S. *Into Thin Air: the Problem of Air Pollution.* New York: Facts on File, 1998. (Gr. 7-12)

Lauber, Patricia. *Who Eats What?: Food Chains and Food Webs.* New York: HarperCollins, 1995.

Leahy, Christopher. *Peterson First Guides: Insects*. Boston: Houghton Mifflin, 1987. (for younger students)

Lewis, Barbara. *Kid's Guide to Social Action*. Minneapolis, MN: Free Spirit Publishing, 1998.

Lynch, Wayne. *A is for Arctic*. Willowdale, Ont.: Firefly Books, 1996.

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McClanahan, Alexandra. J. *Growing Up Native in Alaska*. Anchorage: CIRI Foundation, 2000. (biographies)

Miller, Debbie S. *A Caribou Journey*. Boston: Little, Brown, 1994.

Miller, Debbie S. *Flight of the Golden Plover.* Anchorage: Alaska Northwest Books, 1996.

Miller, Debbie S. *Polar Bear Journey.* Boston: Little, Brown, 1997.

Mowat, Farley. *Never Cry Wolf.* New York: Bantam, 1983. (Gr. 10-12)

Murphy, Claire Rudolf. *Caribou Girl.* Boulder: Roberts Rinehart, 1998.

National Geographic Society. *Atlas of the World.* Washington, D.C., 1999. (or any other world atlas)

Ortega y Gasset. *Meditations on Hunting.* Bozeman, MT: Wilderness Adventures Press, 1995.

Patten, J.M. *Acid Rain.* Vero Beach, FL: Rourke, 1995.

Petersen, David. *A Hunter's Heart: Honest Essays on Blood Sport.* New York: Henry Holt and Company, 1996.

Pielou, E.C. *A Naturalist's Guide to the Arctic.* Chicago: University of Chicago Press, 1994. (Gr. 9-12)

Posewitz, Jim. *Beyond Fair Chase: The Ethic and Tradition of Hunting.* Helena, MT: Falcon Press Publishing Co., 1994.

Pratt, Verna E. *Field Guide To Alaskan Wildflowers.* Anchorage: Alaskakrafts, 1989.

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Williams, Terry Tempest, and Ted Major. *The Secret Language of Snow*. New York: Sierra Club/ Pantheon Books, 1984.

Wilsdon, Christina. *National Audubon Society First Field Guide, Insects.* New York: Scholastic, 1997.

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Yolen, Jane. *Welcome to the Ice House.* New York: Putnam, 1998. (Gr. K-3)

Zwinger, Ann and Beatrice Willard. *Land Above the Trees: A Guide to American Alpine Tundra.* Boulder: Johnson Books, 1996. (Gr. 9-12)

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Acid Rain, the Invisible Threat (video). Fort Collins, CO: Scott Resources Inc., 1995. (Gr. 6-12)

Arctic & Antarctic: Eyewitness (video). New York: Dorling Kindersley, 1996.

DK Science Encyclopedia (CD) New York: Dorling Kindersley. (contains information on seasons, what makes day and night, and the earth's rotation and revolution)

National Audubon Society Specials. *Arctic Refuge: A Vanishing Wilderness* (video). PBS.

Websites

Alaska Department of Fish and Game <www.adfg.alaska.gov> Current hunting seasons and regulations by species and game units; photos of wildlife; wildlife information; environmental education.

Alaska Natural History Program <www.alaska.uaa.edu/enri/aknhp_web> tracks Alaska's plants and wildlife of concern. Links to biodiversity websites.

Alaska Science Forum <www.gi.alaska.edu/ScienceForum> Treasure of new and archived articles written for general audiences answering science questions and

highlighting Alaska's natural science phenomena and research.

Alaska Statewide Databases accessed through local library website or <sled.alaska.edu> have text of magazine and newspaper articles.

Anchorage Daily News <www.adnsearch.com> Staff-written newspaper articles, current and past. Article citations can be located at no charge. For full text, a fee must be paid.

Arctic Circle studies <arcticcircle.uconn.edu> Of particular interest are the items under "Natural Resources."

Arctic National Wildlife Refuge <arctic.fws.gov > shows how ice wedges and permafrost features are created ("Habitat") and has numerous animal photos and information ("Wildlife").

Arctic National Wildlife Refuge: A Special Report. Available on <arcticcircle.uconn.edu/ArcticCircle/ANWR> Presents divergent viewpoints on the development of the Arctic National Wildlife Refuge.

Arctic Power, <www.anwr.org> dedicated to the development of the Arctic National Wildlife Refuge.

Audubon On Line Field Guides <www.enature.com>

Fairbanks Daily News Miner <www.newsminer.com> Staff-written newspaper articles, current and past, available on file, no fee.

Muskox Project <www.muskoxfarm.org> has muskox photos and natural history information.

Thinkquest's Arctic Animals Home <tqjunior.advanced.org/3500> Good for research papers; has extensive links to arctic wildlife. Overview of animals; habitat descriptions, pictures, sounds, stories, activities.

University of California Museum of Paleontology (Berkeley) <www.ucmp.berkeley.edu/fungi/lichens/lichens.html> Introduction to lichens in plain language, with photos and links.

U.S. Fish and Wildlife Service, Alaska Region <www.r7.fws.gov> Photos, endangered species, habitat, and species of concern information on eiders and other migratory birds.

USGS – Alaska Biological Science Center <www.absc.usgs.gov> Wildlife photos and reports of current research on Alaska's fish, mammals, birds, and ecosystems.

Various atlas websites <www.maps.com> or <www.3datlas.com>

Folktales, Fiction, Poetry, Biographies, and Picture Books Supplementing *Alaska's Tundra and Wildlife*

Asch, Frank. *Song of the North*. San Diego: Harcourt Brace, 1999. (poetry)

Bernhard, Emery. *How Snowshoe Hare Rescued the Sun: A Tale from the Arctic*. New York: Holiday House, 1993. (folktale)

Bierhorst, John. *The Dancing Fox: Arctic Folktales*. New York: Morrow, 1997. (folktale)

Cohlene, Terri. *Ka-Ha-Si and the Loon: An Eskimo Legend.* New York: Troll, 1991 (folktale)

Dabcovich, Lydia. *The Polar Bear Son: An Inuit Tale.* New York: Clarion Books, 1999. (folktale)

Dwyer, Mindy. *Aurora: A Tale of the Northern Lights.* Seattle: Alaska Northwest Books, 1997. (picture book)

Dunphy, Madeline. *Here is the Arctic Winter.* New York: Hyperion, 1993. (picture book)

Easley, MaryAnn. *I am the Ice Worm.* Honesdale, PA: Boyds Mill Press, 1996. (fiction Gr. 5+)

Field, Edward. *Magic Words: Poems.* Based on songs and stories of the Netsilik Inuit, collected by Knud Rasmussen. San Diego: Harcourt Brace, 1998. (poetry)

Fox-Davies, Sarah. *Little Caribou.* Cambridge, MA: Candlewick, 1996. (picture book)

Fowler, Susi Gregg. *Circle of Thanks.* New York: Scholastic, 1998. (picture book)

Gallop, Louise. *Owl's Secret.* Homer, Alaska: Paws IV Pub., 1993. (picture book)

George, Jean Craighead. *Arctic Son.* New York: Hyperion, 1997. (picture book)

George, Jean Craighead. *The Case of the Missing Cutthroats.* New York: HarperCollins, 1995.

George, Jean Craighead. *Julie.* New York: HarperCollins, 1994. (fiction Gr. 5+)

George, Jean Craighead. *Julie of the Wolves*. New York: HarperCollins, 1972. (fiction Gr. 5 +)

George, Jean Craighead. *Julie's Wolf Pack.* New York: HarperCollins, 1997. (fiction Gr. 5 +)

George, Jean Craighead. *One Day in the Alpine Tundra.* New York: HarperCollins, 1984.

George, Jean Craighead. *Snow Bear.* New York: Hyperion, 1999. (picture book)

George, Jean Craighead. *Who Really Killed Cock Robin? An Ecological Mystery*. New York: HarperCollins, 1991.

Grindley, Sally. *Polar Bear.* Atlanta: Peacetree Publishers, 1997. (picture book)

Heinz, Brian. *Kayuktuk: An Arctic Quest.* San Francisco: Chronicle Books, 1996. (picture book)

Heinz, Brian. *Nanuk, Lord of the Ice.* New York: Dial, 1998. (picture book)

Houston, James. *Frozen Fire: A Tale of Courage.* New York: Atheneum, 1977 (fiction), and other books by James Houston

Jones, Tim. *More Wild Critters.* Portland: Graphic Arts Center Pub.Co.,1994. (poetry)

Jones, Tim. *Wild Critters.* Portland: Graphic Arts Center Pub. Co., 1993. (poetry)

Joose, Barbara. *Mama, Do You Love Me?* San Francisco: Chronicle Books, 1991. (picture book)

Kusugak, Michael Arvaarluk. *My Arctic 1,2,3.* Toronto: Annick Press, 1996. (picture book)

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Lesser, Carolyn. *Great Crystal Bear.* New York: Harcourt, Brace, 1996. (picture book)

London, Jonathan. *Ice Bear and Little Fox.* New York: Dutton, 1998. (picture book)

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McDonald, Megan. *Tundra Mouse: A Storyknife Tale.* New York: Orchard Books, 1997. (folktale)

Murie, Margaret. *Two in the Far North.* Seattle: Alaska Northwest Books, 1997. (biography) (Gr. 9-12)

Murphy, Claire Rudolf. *Caribou Girl.* Boulder: Roberts Rinehart, 1998. (fiction)

Nicolai, Margaret. *Kitaq Goes Ice Fishing.* Seattle: Alaska Northwest Books, 1998. (picture book)

Norman, Howard. *The Girl who Dreamed Only Geese: and Other Tales of the Far North.* New York: Harcourt Brace, 1997. (folktales)

Pinczes. Elinor. *Arctic Fives Arrive.* Boston: Houghton Mifflin, 1996. (picture book)

Pullman, Philip. *The Golden Compass.* New York: Alfred A. Knopf, 1996. (fiction) (Gr. 7-12)

Ryder, Joanne. *Winter White.* New York: Morrow Junior Books, 1997. (picture book)

Sabuda, Robert. *The Blizzard's Robe.* New York: Atheneum, 1999. (picture book)

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