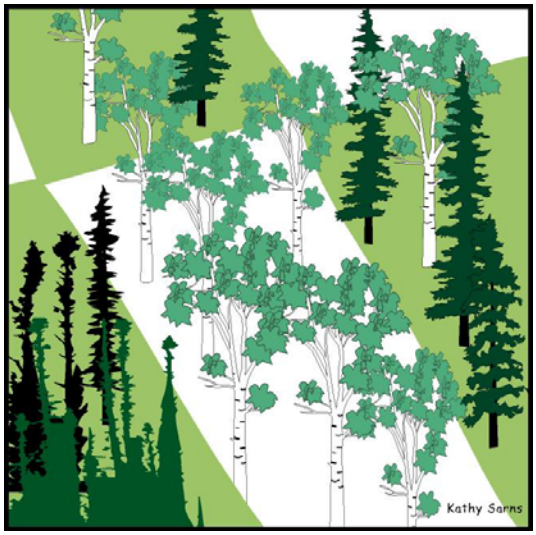
FOREST AND TUNDRA ECOLOGY BACKGROUND

Central and western Alaska are dominated by two major ecosystems, the boreal forest and the tundra. Although these ecosystems look very different, they are similar in many ways.

WHAT IS THE BOREAL FOREST?

The boreal forest is the largest and northern most forest ecosystem in the world. The boreal forest is the predominant ecosystem in interior Alaska. Viewed from the air, this forest looks like a giant patchwork quilt or mosaic. Large patches of scraggly black spruce trees on poorly drained and permafrost soils, contrast with hillsides of light green birch, aspen and tall white spruce.



WHAT IS THE TUNDRA?

Tundra is an environment characterized mainly by the absence of trees. At first glance, tundra appears monotonously the same. But closer examination reveals that, like the boreal forest, the tundra is a mosaic. It is a mosaic of wet, sedge-grass meadows, thickets of low shrubs, and dry areas vegetated by cushion and mat-forming plants.

Tundra occurs predominantly at higher elevations and in the western and northern areas of Alaska (Figure 1). However, the boreal forest and tundra frequently occur together. Patches of tundra are often found within the boreal forest areas, and patches of forest can be found in tundra areas.

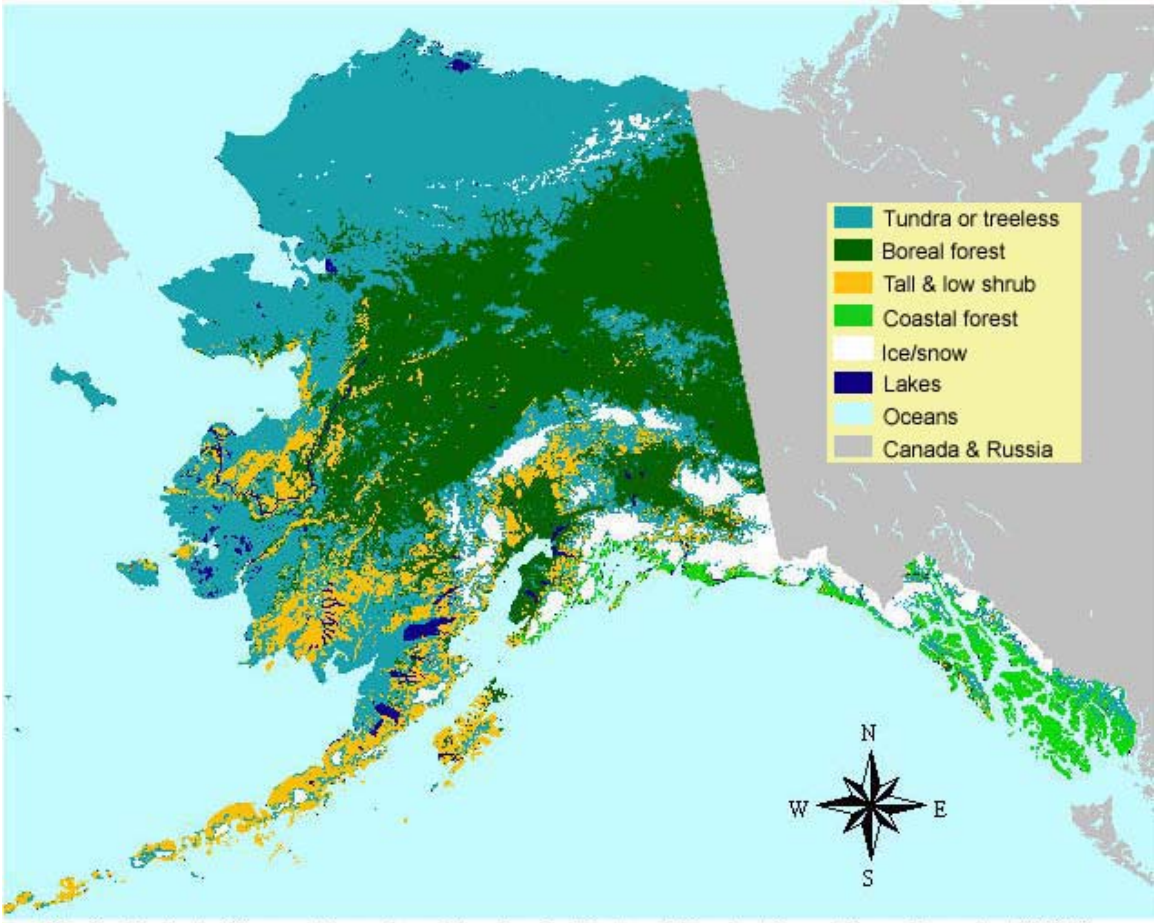


Fig. 1 - Extent of boreal forest and tundra in Alaska. Adapted from Flemming et.al. (1991)

WHAT ARE THE NONLIVING COMPONENTS OF BOREAL FOREST AND TUNDRA?

Like all land ecosystems, Alaska boreal forest and tundra include the nonliving components of air, water, soil, and energy (in the form of sunlight). These form the physical surroundings of the ecosystem. Some physical features of the boreal forest and tundra are:

1. strong seasonal patterns (severe winters and short, warm summers)
2. permafrost
3. little precipitation
4. lightning-caused fires
5. ice jams and floods

Seasonal Patterns

In winter, when the northern regions are tilted away from the sun, the land receives only a few hours of light each day. During these few hours, the sun barely rises above the horizon. The winter sun delivers little heat and light to the forest and tundra, and more heat is lost to the atmosphere than is received from sunlight. Winter air temperatures plunge below zero, often reaching extremes of -40 F (-40 C) or colder.

During summer when the earth's northern latitudes are tilted towards the sun, day length is nearly 24 hours and the sun rises higher above the horizon and delivers more light and heat per hour. The boreal forest and tundra then receive more heat in sunlight than they lose. Thus, temperatures rise. Air temperature extremes above 90 F (32.2 C) regularly occur in the boreal forest. In the tundra, summer temperatures are usually cooler, but may still reach extremes of 68 F (20 C).

Permafrost

Despite the warmth of summer, the climates of both the boreal forest and tundra are dominated by the severe cold of winter. Thus, permafrost, or permanently frozen ground, occurs in some areas. Surface soils called the active layer thaw out each summer and refreeze in winter. Beneath the active layer, permafrost remains frozen year-round. In these northern areas, permafrost is continuous, occurring everywhere. In other areas of the state, permafrost is discontinuous, occurring only in some places but not everywhere. Where permafrost is discontinuous, it generally underlies north-facing hillsides and poorly drained lowlands. Permafrost is absent from most south-facing

Permafrost underlies most tundra areas and occurs throughout the northern portions of the boreal forest. hillsides and from the well-drained sandy soils around large bodies of water. In the southernmost reaches of the boreal forest, permafrost is sporadic or absent (Figure 2).

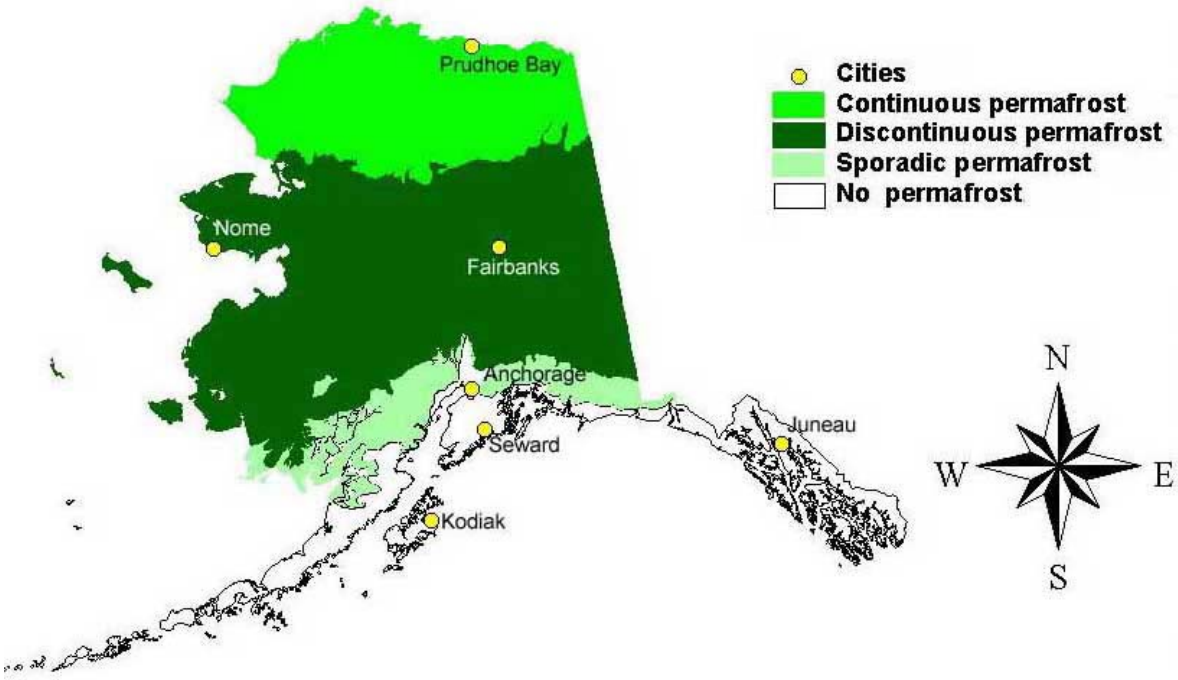


Fig. 2 - Permafrost areas in Alaska. Adapted from Ferrians et al.

Precipitation

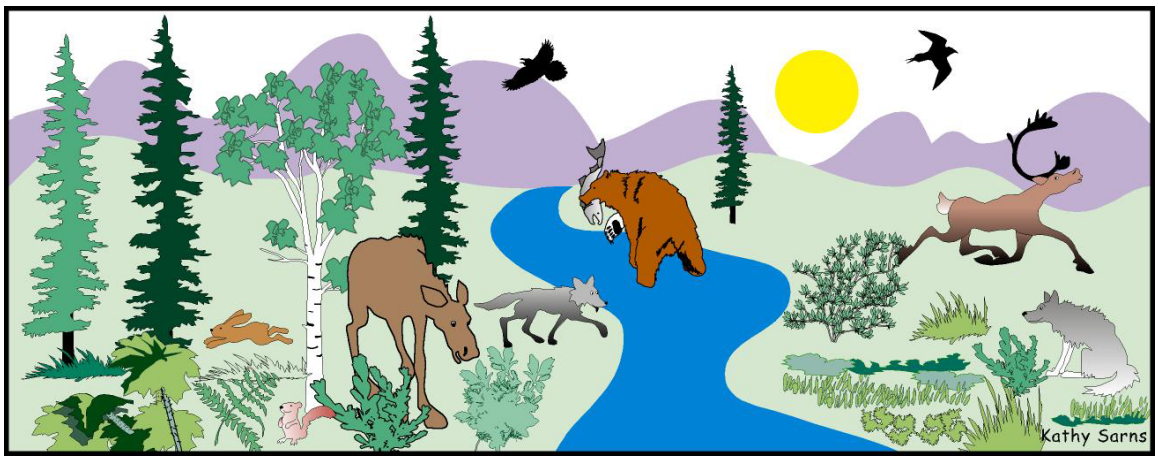
The boreal forest and tundra receive little precipitation; in both ecosystems the average annual precipitation is only 5 to 12 inches (120-300 mm). This is similar to the amount of precipitation in many deserts of the world. However, unlike a desert, many sites in the tundra and boreal forest are moist or wet. Moist and wet conditions occur despite low precipitation partly because cool temperatures cause low evaporation rates. In addition,

water cannot seep into permafrost soils.

Fire
Wildland fires caused by lightning are a natural part of Alaska's boreal forest and tundra ecosystems. Layers of charcoal in lake beds, wetlands, fire-scarred trees, and logs provide evidence that fires have occurred in the boreal forest environment for thousands of years. Due to the absence of trees, tundra fires leave little long-lasting evidence of their passage. Therefore, the history of fire in tundra regions is less clear. Based on historical fire records, scientists think fires naturally occur in some tundra regions, such as the Seward Peninsula, but are rare or absent from other tundra areas. In general, fires occur less frequently and burn smaller areas in tundra than in the boreal forest. However, large tundra fires have been recorded. Fire is one of the greatest forces of change in the boreal forest and tundra.

Ice Jams and Flooding
During spring thaw, ice quickly breaks up on the rivers of Alaska. The ice pushes it's way downstream, scouring the banks and often leaving tree and plant roots exposed. This ice can also pile into ice jams which may dam the river and cause extensive flooding.

WHAT ARE THE LIVING COMPONENTS OF THE BOREAL FOREST AND TUNDRA?



Many kinds of living things inhabit the boreal forest and tundra, including microscopic organisms, fungi, plants, and a wide variety of animals (insects and other invertebrates, birds, and mammals).

Microscopic Organisms
The **microscopic organisms** of the boreal forest and tundra include bacteria, algae, and protozoa. These creatures are easy to overlook since a microscope is needed to observe them. But, they are important parts of the forest and tundra. They live in the soil, water, and air and inside other living things.

Fungi and Lichens

Fungi of the boreal forest and tundra include mushrooms, molds, rusts, mildews, and rots. Most are important **decomposers**, meaning they help break down or decay dead plants and animals. Other fungi live together with certain kinds of algae and are called lichens. **Lichens**, like plants, **photosynthesize** (they convert air, water, and sunlight into sugars for food). Lichens are a dominant organism in some tundra regions and an important nutrient source for caribou.

Plants

Plants are the most noticeable of the living components of both the boreal forest and tundra. The dominant species of trees of the boreal forest include black and white spruce, birch, aspen, and balsam poplar. A variety of shrubs, herbs, grasses, mosses, and ferns grow in association with these trees. The boreal forest is often classified into several forest cover types based on the dominant species of trees and associated plants.

Tundra areas are predominately treeless, but the dominant tundra plants vary from area to area. Mosses and sedges are the most abundant plants in wet tundra. In moist sites, dryas, dwarf shrubs such as willow, bog birch, crowberry, and Labrador tea are important. Mat and cushion plants such as moss campion and arctic bearberry grow in dry tundra.

Animals

The animals of the boreal forest and tundra include birds, mammals, amphibians, and insects and other invertebrates. See the *Alaska Ecology Cards* for a detailed listing.

<u>Birds</u>

Birds of the boreal forest and tundra of Alaska include residents (birds that live here year-round) and migrants (birds that nest here but winter elsewhere).

Typical boreal forest bird residents include gray jays, black-capped chickadees, redpolls, pine grosbeaks, and common ravens; hairy, downy, three-toed, and black-backed woodpeckers; ruffed and spruce grouse; boreal, great-horned, great gray, and hawk owls; and goshawks. Migrant birds include several thrushes, warblers, swallows, sparrows, and waterfowl.

Few bird species are tundra residents, but a wide variety of migrants return to the tundra each year to nest. The few resident species include ptarmigan, snowy owls, and ravens. Common migrant species include loons, ducks, geese, swans, shorebirds (plovers, sandpipers, phalaropes, gulls, and jaegers), short-eared owls, rough-legged hawks, and a few songbirds (snow buntings, Lapland longspurs, and water pipits).

<u>Mammals</u>

Many of the same species of mammals live in both the boreal forest and tundra. Common species of the boreal forest include moose, caribou, snowshoe hares, red-backed voles, red squirrels, beavers, porcupines, coyotes, red fox, pine marten, wolves, and black and brown bears. Common tundra

species include moose, caribou, voles, lemmings, arctic ground squirrels, red fox and arctic fox, wolves, wolverines, and brown bears.

Did you know that voles are some of the first mammals to re-establish homes in an area after a fire? Voles play a critical role in Alaskan ecosystems because they help distribute plant seeds throughout the burned area and they provide food for many birds and mammals. Alaska has 7 species of voles. Yellow-cheeked voles, and red backed voles are some of the most common. Do you know what types of voles are found in your part of the state?

Throughout this document we have a very special vole, Vince, who is often found in unusual places (for a vole). Look for Vince in the pictures!

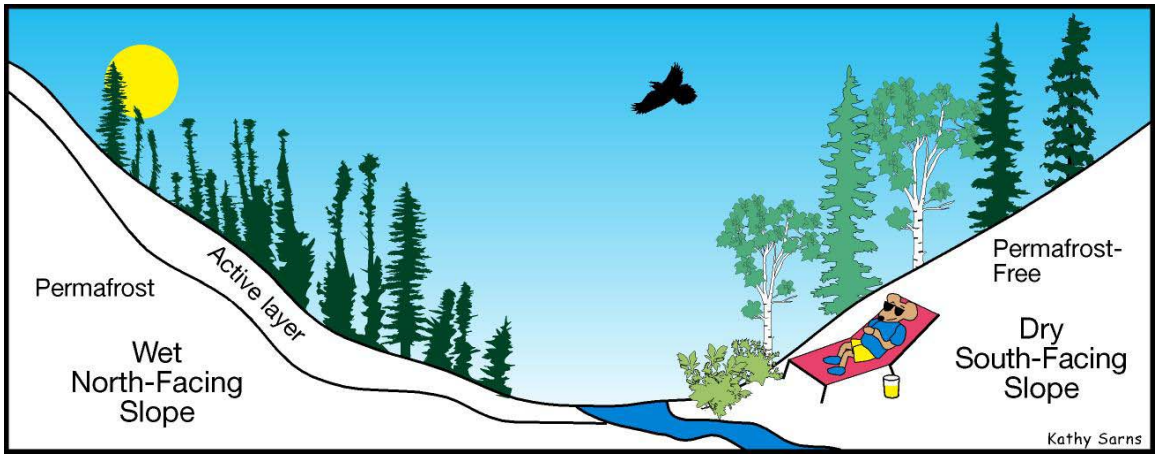
Amphibians

The wood frog is the only amphibian that occurs throughout the boreal forest in Alaska. The wood frog is absent from most tundra areas, though it has been recorded in a few locations.

Invertebrates

Invertebrates (animals without backbones) are the most abundant animals in both the boreal forest and tundra. Despite their small sizes, the combined weight of all invertebrates is greater than the combined weight of all mammals and birds. Invertebrate animals live in the soil and water and on plants. Ants, bees, wasps, butterflies, moths, mosquitoes, lacewings, aphids, beetles, leaf hoppers, and dragonflies are just a few of the kinds of insects that occur in these environments. Centipedes, spiders, mites, slugs, and segmented worms are some of the other invertebrate groups that occur.

HOW DO THE NONLIVING COMPONENTS AFFECT THE LIVING THINGS?



The strong seasonal patterns, permafrost, and low precipitation of the boreal forest and tundra combine with the **topography** (landforms) to create a mosaic of physical environments. The **mosaic** is most visible in the boreal forest. There, in areas of discontinuous permafrost, most south-facing hillsides are relatively warm, dry, and free of permafrost. In contrast, north-facing hillsides and poorly drained lowlands are cool, wet, and underlain by permafrost.

Since plants are adapted to specific environmental conditions, these different physical environments create a mosaic of forest types. Warm, dry, south-facing hillsides and well-drained sites along rivers provide conditions suitable for aspen, birch, balsam poplar, and white spruce. Black spruce and tamarack (or larch) are permafrost indicators and dominate in the cold, wet soils.

A similar but less obvious mosaic occurs in tundra. In most tundra areas, permafrost is continuous, but the depth of the active layer (the layer of soil that thaws each year) varies depending on the topography and soil. Freezing and thawing of the active layer over the permafrost creates a variety of landform features such as pingos (mounds of earth formed by frost action) and polygons (blocks on the soil surface caused by freezing and thawing.) Soils high in clay content tend to inhibit drainage while gravely soils allow better percolation. Flat, low-lying sites tend to be flooded or wet, while slightly elevated or sloped sites may be well drained and drier. Certain plants grow best in wet sites; others prefer the drier sites. In many tundra areas, a few inches of elevation change results in a very different physical environment and a complete change in the plant species present. In a very small area one may find dry tundra plants on top of **tussocks** and wet tundra plants in between.

This continually evolving mosaic of forest and tundra types created by environmental variation is complicated. It is constantly modified by physical factors such as fire, floods, drought and frost action. Living organisms affect the mosaic in several ways. Insects kill trees. Beavers dam streams and flood forests. Humans change the mosaic by logging, mining, development, and land clearing. These events and actions affect the mosaic by changing the pattern of succession.

WHAT IS SUCCESSION?

Succession is the natural, orderly change in plant and animal communities that occurs over time. The successsional timeline has been divided into stages that portray the slow, continuous changes in an environment. When an existing environment is disturbed by fire, insects, development, resource extraction, flood, or extreme weather, it generally reverts to an earlier successional stage. Herbs and shrubs dominate the earliest stages of succession. Intermediate stages follow, dominated by tall shrubs and young trees. Finally, a mature forest stage and a climax forest stage may follow. The pace of succession may be affected by soil conditions, climate, permafrost, topography, and natural forces. See Succession of the Boreal Forest After Fire handout.

Each species of plant has particular **habitat** requirements. These habitat requirements include specific amounts of light, heat, soil nutrients, and water. As succession occurs, tall plants create shade. Layers of moss insulate the soil and cause a drop in soil temperatures. More and more minerals become tied up in living and dead plant material. These changes in the physical environment change the suitability of a site for different plant species. The species and numbers of plants present change as the physical conditions of the environment change.

Like plants, wildlife also has specific habitat requirements. Each species of animal needs the right kinds and amounts of food, water, cover, and space; wildlife populations change during succession, too.

Succession strongly affects wildlife use of the boreal forest. Some wildlife, such as white-crowned sparrows fulfill their habitat needs in the shrub thickets of early forest succession stages. Others, such as white-winged crossbills, need large expanses of mature spruce forests to survive. Much boreal forest wildlife need a mixture of forest ages to meet their habitat needs. Snowshoe hares are a good example. Young willow and birch shrubs, which flourish in the early stages of succession, provide the food snowshoe hares need. But, when seeking shelter either from a predator or winter weather, hare need the shelter provided by the

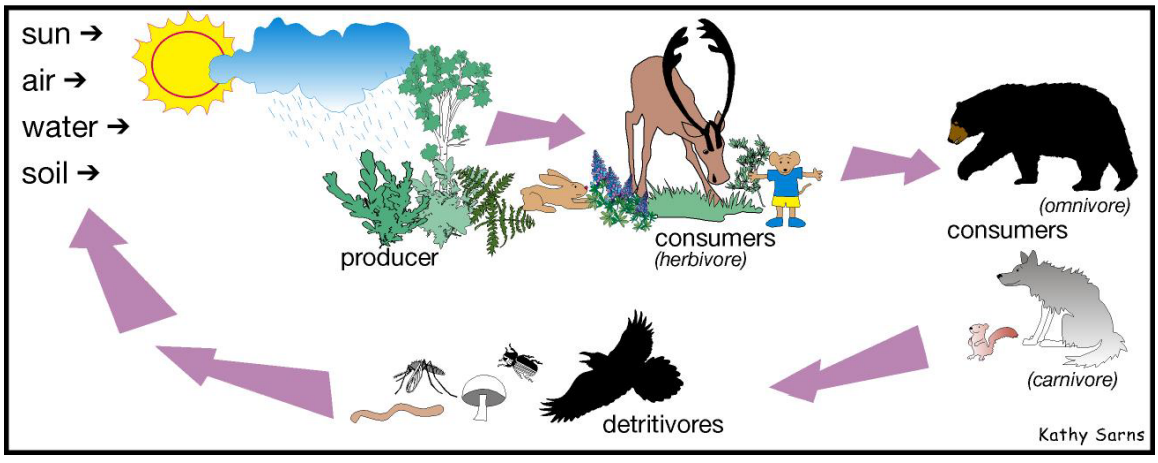
spruce forest. The area where several habitats meet is called an **edge** and generally holds the largest diversity of wildlife.

Succession exists in the tundra as it does in the boreal forest, although it is not as clearly understood and is extremely slow in comparison. Early succession is visible where lake levels have lowered and plants grow on the newly drained soil. Cottongrass tussocks take a long time to establish and don't grow in recently disturbed sites; if cotton grass is evident, then the area is probably in the later successional stages. Trees or shrubs with thick, gnarled, lichen covered stems are found in the later successional stages as well. Because little research has been done regarding tundra succession, less is known about its effects on plant and animal communities.

IN WHAT WAYS DO THE LIVING AND NONLIVING COMPONENTS OF THE BOREAL FOREST AND TUNDRA INTERACT?

A **food chain** describes the path of energy and nutrients from the nonliving parts of the ecosystem, through the living components, and back to the nonliving environment. By cycling nutrients, food chains connect the nonliving and living components of the boreal forest and tundra.

The basic link of every food chain is formed by the energy and minerals in the nonliving components of air, water, soil, and sunlight. Most organisms cannot use energy and minerals directly from the nonliving environment. Those organisms that can are called **producers** and form the next link in the food chain. They are called producers because they make, or produce, food for themselves and all other living things. Plants are the most important producers in the forests and tundra; lichens, algae, and some bacteria are also producers.



Consumers form the next link in food chains. All organisms other

than producers are called consumers because they obtain energy and minerals by consuming (eating) other living things.

Consumers are grouped according to the type of foods they eat. **Herbivores** eat producers such as plants. Herbivores of the boreal forest and tundra include moose, caribou, voles, lemmings, grouse, redpolls, and many insects and other invertebrates. Carnivores eat these herbivores. **Carnivores** include meat-eating animals such as wolves, coyotes, foxes, lynx, owls, jaegers, hawks, and insect-eating animals such as chickadees, warblers, shrews, centipedes, spiders, and dragonflies. Some consumers feed on a wide variety of organisms, including both living and dead plants and animals. These consumers are called **omnivores**.

Producers and consumers store some energy and nutrients in their tissues. They also lose energy and minerals in their wastes and use some energy to move around and grow. Consumers that eat dead organisms and waste materials are called **detritivores**. Detritivores include some large animals such as ravens; but the most important detritivores of the forest and tundra are invertebrates, fungi, and microscopic organisms. Many of these live in the soil where most of the dead organisms, animal droppings, and other waste materials accumulate.

The process of waste materials being broken down and decayed by detritivores is **decomposition**. The minerals and nonliving materials released by decomposition are returned to the soil and air to possibly be reused by producers.

DOES SUCCESSION AFFECT THE PROCESSES OF PRODUCTION AND DECOMPOSITION?

Energy flow in the boreal forest is continually changing. The total amount of organic material manufactured by producers (**annual production**) is greater in early successional stages (particularly following fire). In early succession, the fast growth of herbs, shrubs, and deciduous trees results in high annual production. In contrast, annual production in late succession is lower and is dominated by mosses, lichens, and spruce trees. This affects the food chain as few consumers can digest mosses, lichens, or spruce needles. Thus, fewer consumers live in mature aging forests than in younger forest stands.

Decomposition occurs more rapidly in young forests than in older ones. Spruce needles and mosses are difficult to decompose and soil temperatures in older successional stages are often lower due to the insulating effects of the organic mat and the shading effect of larger trees.

The effects of succession on production and decomposition rates in tundra have not been well documented. There is some evidence that annual production and flowering of some plants increases during the first years following a

tundra fire due to the warmer, mineral-rich soil. Increased depth of the active layer also leads to faster rates of decomposition during the initial years following fire. In the long-term, however, lush plant growth resulting from fire may increase the insulation of the soil. This ultimately decreases the depth of the active layer and thus decreases decomposition and production rates. More research is needed on the complex interactions between fires, plant succession, production, and decomposition in tundra areas.

HOW DO LIVING THINGS AFFECT THE PHYSICAL ENVIRONMENT?

Plants of the boreal forest and tundra also affect the occurrence of fires. Fires could not occur if not for the fuel provided by the growth and accumulation of plant materials (wood, branches, dead leaves and stems, and dead mosses). These accumulated fuels decompose slowly due to cool soil temperatures. The plant species mix also influences the extent and intensity of fires due to variation in growth forms and chemical composition. Heaths (such as blueberries, cranberries, huckleberries, and Labrador tea) contain volatile compounds and are highly flammable. They allow surface fires to start and spread quickly. The drooping branches of black spruce also aid the spread of fire by providing a continuous fuel ladder from the ground to the crowns of trees.

Animal activities may also affect the occurrence of fire. For example, outbreaks of certain insects such as bark beetles can kill hundreds of trees and create optimum conditions for a fire to start and spread. Beavers help to prevent the spread of fires by creating large ponds that act as fire breaks; conversely they enhance the chances of fire by injuring and killing trees which then provide more available fuel. Large piles of spruce cone bracts created by red squirrels provide sources of dry fuel.

Animals may also influence the kind and density of plants that occur,

which in turn, affects the occurrence of fire. Some scientists have suggested that the prevalence of highly flammable, oily and resinous plants (such as spruces and certain shrubs) is the result of selective grazing and browsing on more palatable species by wildlife. In some cases, intensive browsing of shrubs and saplings by moose and hares may slow the rate of plant succession. Thus, the frequencies and intensities of forest and tundra fires may be influenced by the animals, as well as by the plants and physical conditions of these environments.