PART 2 – TERRESTRIAL ECOSYSTEMS OF NORTH AMERICA

Ecological Principles Applied to North American Biomes

Abiotic Factors of Biomes

Biotic Features of Biomes – Organisms

- Not intended to be a taxonomic event
- Instead, emphasis on adaptations of common plants and animals for each biome
- Common members of food chains and food webs of each biome
- Limiting factors for each biome

North American Biomes

1 Arctic Tundra

2 Boreal or Taiga

3 Rocky Mt. Evergreen

4 Pacific Coast Evergreen

5 Northern Mixed

6 Eastern Deciduous

7 Coastal Plain Evergreen

8 Mexican Montane

9 Rain Forest/Selva

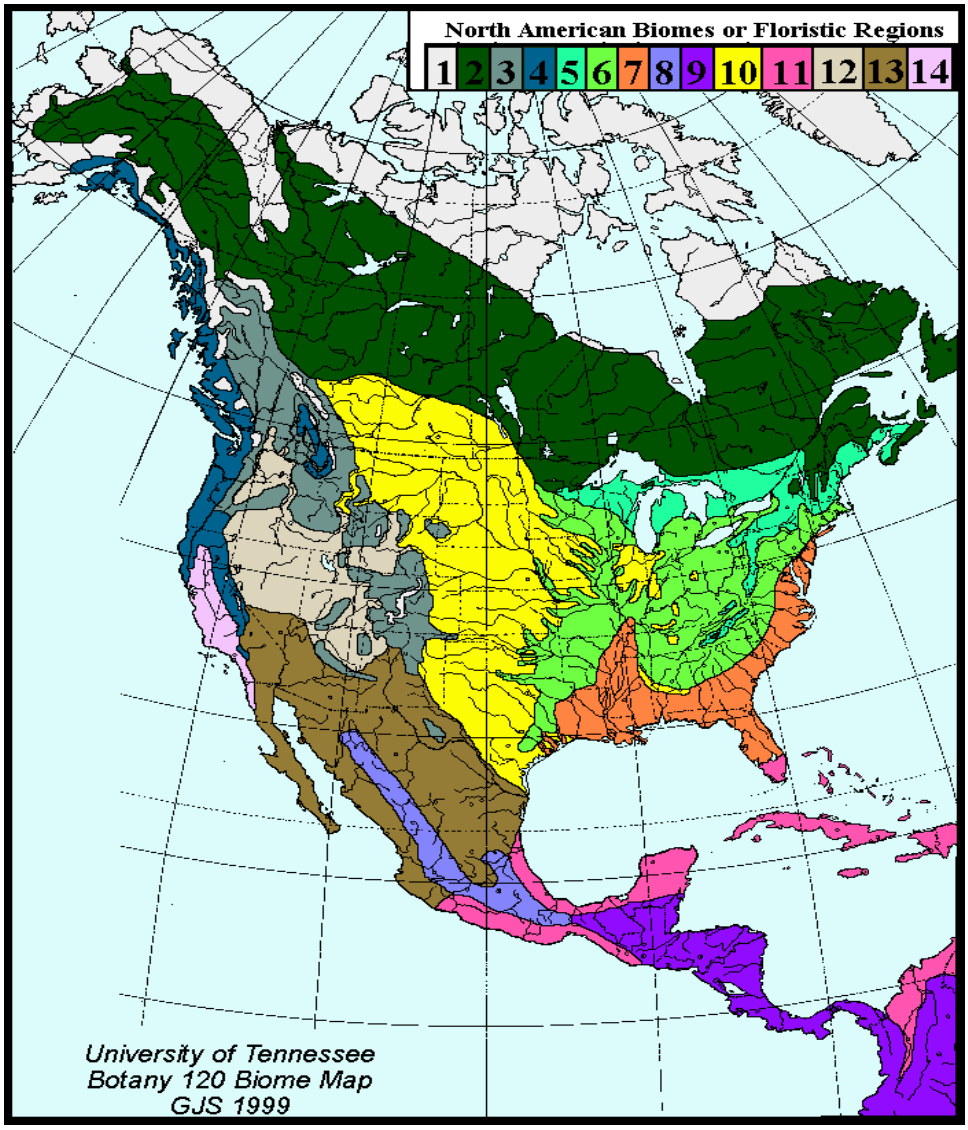
10 Prairie

11 Tropical Savanna

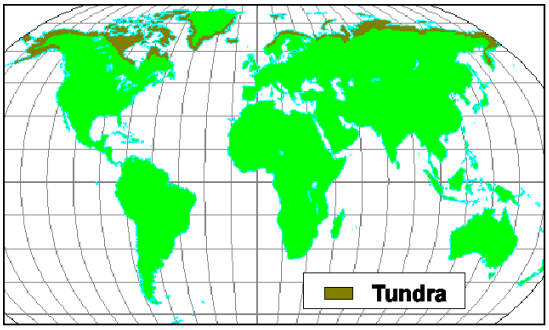
12 Cool Desert

13 Hot Desert

14 Mediterranean Scrub

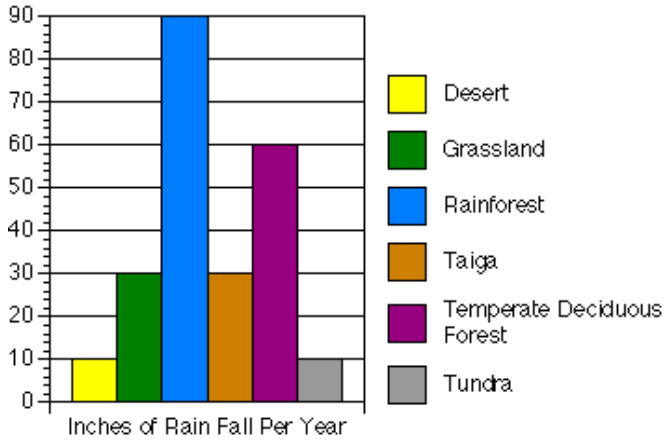


TUNDRA



Characteristics of Tundra:

- About one fifth of the land surface of the Earth is tundra.
- Located next to icy zones - the treeless regions in the arctic encircling the North Pole down to Taiga. (**Arctic Tundra**)
- Located at the top of mountains above the tree line (**Alpine Tundra**)
- Extremely cold climate - from **-30°C to -40°C in winter;** average winter temperature of -34 degrees C (-30 degrees F)
- Annual precipitation (mostly snow) is six to ten inches (15 to 25 cm), making it desert-like
- Winds often reach speeds of 30 to 60 miles per hour (48 to 97 km/hr)
- During the winter, there are only a few hours or less of sunlight. In the summer, there is sunlight almost 24 hours a day.
- Ground surface is spongy and uneven as a result of freezing and thawing
- Plains of tundra are covered with snow, ice, and frozen soil most of the year (**permafrost**)



- Highest summer temperature is only about 10° C
- Short season of growth and reproduction of all biomes - from 50 to 60 days
- Low biotic diversity - only about 1700 varieties of plants and about 48 varieties of land mammals
- Simple vegetation structure
- Limitation of drainage
- Energy and nutrients in the form of dead organic material
- Large population oscillations

Types of Plants

- About 1,700 kinds of plants
- Tiny flowering plants (4 inches or less in height)
- grasses
- lichens – crustose and foliose
- sedges
- willows

Plant Adaptations

- Many of the plants are perennials so they can store food from season to season
- Must adapt to strong winds and disturbances in soil
- Plants are short and group together
- Form little cushions or mats close to the ground where ground is warmer than the air
- Carry out photosynthesis at low temperatures and low light intensities
- Adapt to short growing seasons by reproducing asexually rather than sexually

Types of Animals

- Primary consumers (Herbivores) – lemmings, insects, musk oxen, reindeer,
- Secondary consumers (Carnivores) – snow owls, arctic foxes, polar bears
- Migratory birds: ravens, snow buntings, falcons, loons, sandpipers, terns, snow birds, and various species of gulls
- Insects: mosquitoes, flies, moths, grasshoppers, blackflies, and arctic bumble bees
- Fish: cod, flatfish, salmon, and trout
- Reptiles and amphibians are few or absent

Animal Adaptations

- Must adapt to extremely cold winters
- Breed and raise their young very quickly during the short summers
- Many birds migrate south in the winter
- Many of those that stay hibernate during the winter
- Constant immigration and emigration leads to constant oscillations in population

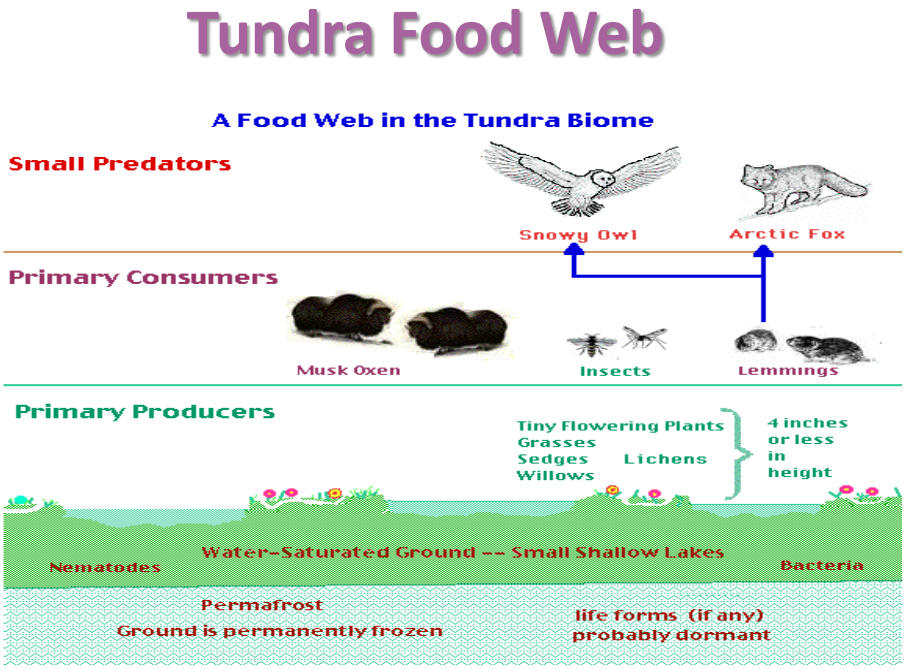
Detritus Eaters

- Bacteria, Nematodes

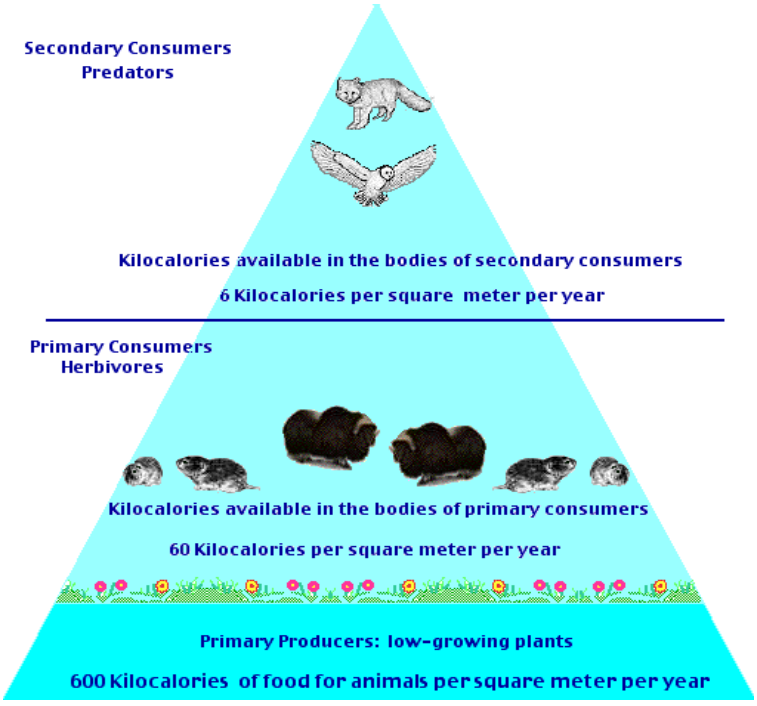
Environmental importance of the Tundra

- Filters millions of liters of water
- Stores large amounts of carbon
- The permafrost layers don't normally thaw out, so the organic matter stored in them is effectively trapped forever. This allows scientists to extract ice cores beneath the Earth's surface for research, allowing us to better understand things such as CO2 concentrations over Earth's history.
- Global warming lowers the thaw depth, inputting CO_2 into the atmosphere when the peat and organic matter begins to decay

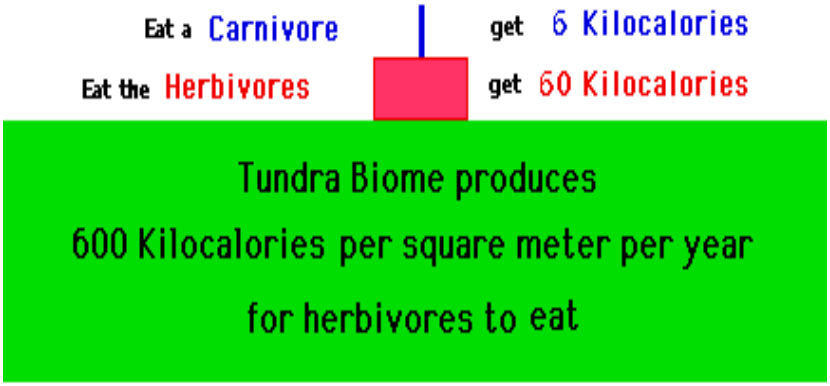
TUNDRA FOOD WEB



TUNDRA ENERGY PYRAMID



ENERGY AT EACH TROPHIC LEVEL OF THE TUNDRA



Conservation Concerns for Tundra OBJ

- Large scale extraction industries (oil, gas, and minerals such as uranium)
- Pollution – chemical waste, mining, hydroelectric development
- Expansion of agriculture/livestock, vehicular traffic, and tourism increase degradation
- Global warming – 1/3 of soil-bound carbon is found in this area.
- Melting of permafrost releases large amounts of carbon into the atmosphere, increasing the "Greenhouse Effect" as organic matter decays and releases carbon dioxide.
- In Arctic tundra, erosion is increasing due to permafrost thaw and overgrazing
- Poaching – hunting and fishing out of season, on protected land, or targeting endangered species
- Like deserts, the plant systems are fragile and the ground bears human traffic marks for years
- The tundra has short food chains and only a few species of animals – a fragile ecosystem. The balance can be upset greatly if a species is reduced or diseased, either by overhunting or predation

Role of Tundra in regulating the Earth's climate

- In the tundra, global warming is happening at twice the rate of more temperate regions of the Earth
- Affects the release or retention of greenhouse gases such as carbon dioxide and methane
- Methane is 20 times more efficient at trapping warmth than carbon dioxide
- Soil nutrients, plant type, and plant biomass will be affected by changes in soil moisture and can modify the amount and types of greenhouse gases
- The climate balance could tip not just in the Arctic, but throughout the world

TAIGA

Characteristics of Taiga (Coniferous or Boreal Forests):

- 2nd largest forest in the world
- Ring between Arctic and Deciduous Forest – 50 to 60 degrees North Latitude
- Upper elevations of Mountains
- Angle of incidence for incoming solar radiation is low and twilight lasts many hours
- Seasons are divided into short, moist and moderately warm summers and long, cold, dry winters
- Temperature varies greatly from summer to winter (-65 to +70 degrees Fahrenheit)
- Variable precipitation: 6-40 in (15-100 cm).
- Soils – thin because they were scraped by glaciers and very acidic because of decomposition of pine needles
- Absence of Earth-churning invertebrates such as earthworms so soil is hard and compact
- Fire is a major factor in maintaining the biome

Environmental importance of the Taiga

- Filters millions of liters of water
- Stores large amounts of carbon
- Produces oxygen
- Rebuilds soils and restores nutrients
- Bogs and marshes provide habitats for large numbers of species from fish to birds

Types of Plants

- Conifers are major producer
- Most common types – spruce, balsam fir, and pine
- Others – hemlock, cedar, redwood, junipers
- Latitude and altitude influences species
- Berry-producing shrubs important to birds, mammals, and people
- Some types of fungi, lichens, and mosses

Plant Adaptations

- Trees have upside-down cone shape so snow slides off the branches
- Branches are flexible to hold great amounts of snow and not break
- Trees grow thin and close together to protect them from cold and wind
- Needles are waxy for protection from freezing temperatures. This prevents them from drying out
- Needles are present year-round and are deep green to absorb maximum warmth from the sun
- Trees have thick bark that does not easily burn and protects inner layers from heat. Seeds are protected by cones.

Types of Animals

- Insects – millions of insects in the summer help to feed the migratory birds
- Birds – up to 3 billion insect-eating birds breed each year in Taiga – over 200 species

- Seed eaters like finches and sparrows as well as omnivorous birds such as crows stay all year
- Different species have adaptations for living with plants in the taiga. Crossbill has specialized bill for prying open cones and nuthatch can break the cones open
- Herbivores such as small mammals, snowshoe rabbits, red squirrels, voles, and lemming

- Predators feeding on small mammals include owls, wolves, lynx, bobcats, minks, wolverines, weasels, mink, otters, martens, fishers. Deer, elk, and moose are large herbivores
- Largest predators such as grizzlies, lynx, and mountain lions will also feed on weakened or young deer, elk, or moose

Animal Adaptations – for very long, cold winters and short, warm summers

- Birds migrate south in winter
- Animals go into hibernation during winter
- others store extra fat layers on their bodies for winter
- Some animals change diets from season to season
- grow extra fur on the bottom of their feet to tread on snow easier (lynx and snowshoe rabbit)
- change fur color and coat thickness from season to season
- live under snow in winter in snow tunnels (lemmings, mice, shrews, voles)

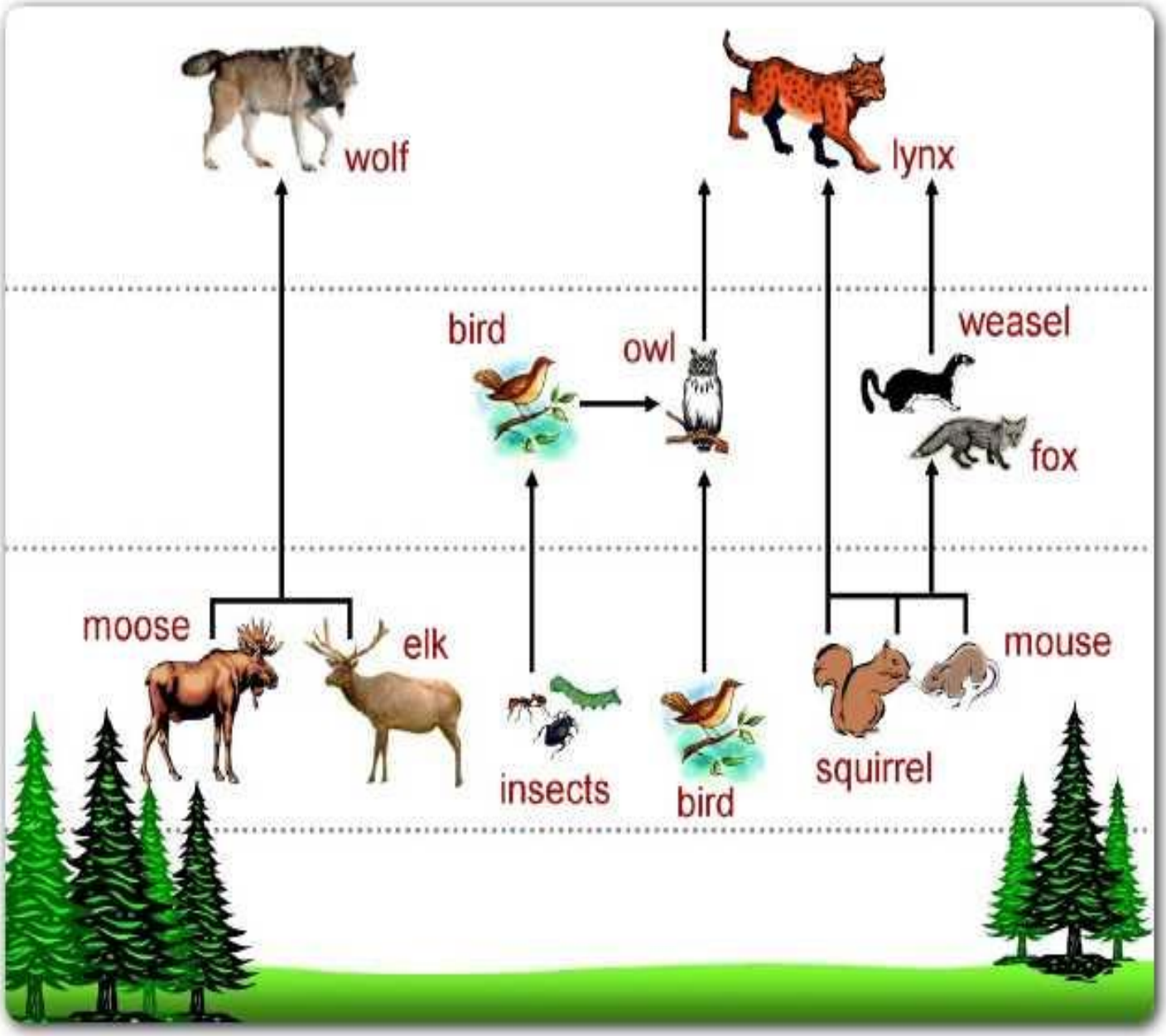
Conservation Concerns for Taiga (Boreal Forest)

- Pollution – chemical waste, mining, hydroelectric development
- Clear cutting – trees are cut in large sections, leaving no protection for wildlife or soil
    - 2.5 million acres are harvested per year with 2/3 going for newspapers promotional mailings and catalogs, which end up in landfills
- Illegal logging – logging in national parks and other protected areas without government permission
- Poaching – hunting and fishing out of season, on protected land, or targeting endangered species
- Forest fires – unnatural fires caused by careless humans.
- Mining – can destroy wildlife habitat
- Drilling for oil and natural gas disrupt the forest
- Global warming

Role of Taiga in regulating the Earth's climate

- It stores large quantities of carbon stored as plant material on forest floor (up to 10 feet in some areas)
- 1 cm of plant material can hold 2.5 tons of carbon per acre
- Taiga acts like a large refrigerator, preventing fallen trees, needles, and other debris from decomposing (decomposition puts carbon dioxide into the atmosphere)
- Heating up the taiga is causing the following problems:
    - Litter begins to decompose, putting carbon into the atmosphere
    - Increases in forest fires
    - Infestation by bark beetles, which is killing the trees and forming tinder to fuel the forest fires and adding more carbon dioxide into the atmosphere

TAIGA FOOD WEB

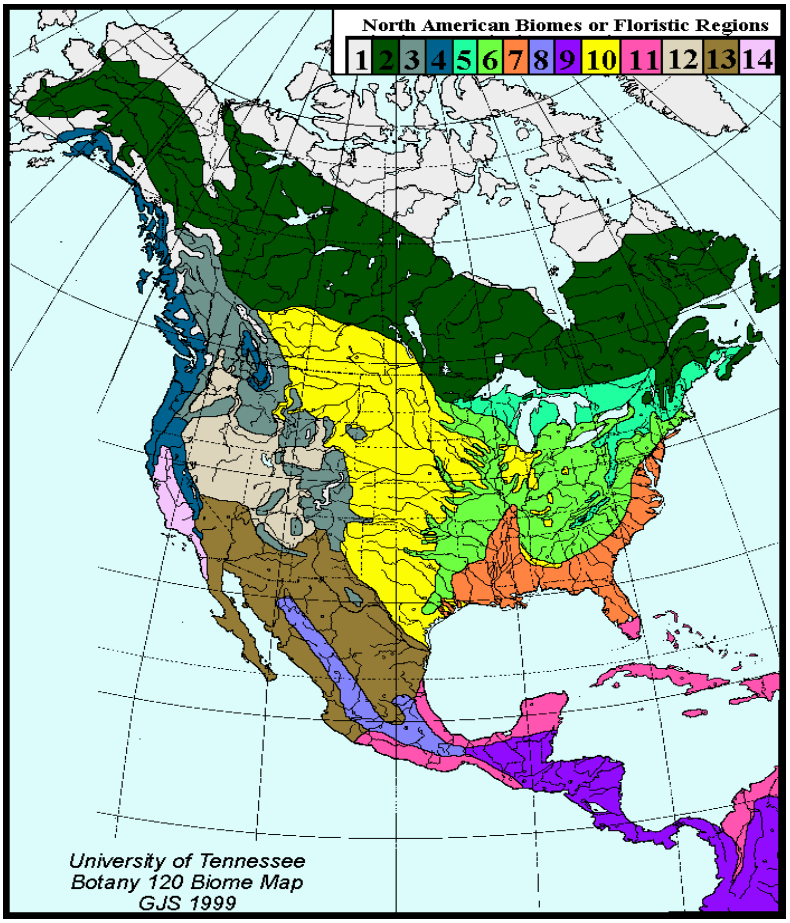


FORESTS

A forest biome is a zone where predictable tree, plant, and animal communities exist resulting from the effects of climate, soil, the presence or lack of moisture and other physical variables.

Characteristics of Forests:

- **Trees dominate the forest biome** – major producer
- **One-third of Earth's land area** – as forests
- **Global climate-buffering capacity in forests**
- **Most diverse biotic communities in the world**
- **Over two-thirds of the leaf area of land plants –** photosynthesis
- **About 70% of carbon present in living things –** carbon cycle
- **Canopy** - affects other producers, consumers, decomposers, and their niches
- **Insects, birds, and mammals** – key components of food web
- **Potential medicines and many thousands of unseen and undiscovered species**
- **Human civilizations** – bringing deforestation, pollution, and industrial usage problems
- **Forest types** – depend upon climate (latitude) and seasonal rainfall
  - Tropical
  - Temperate or Deciduous
  - Boreal (taiga) or coniferous



TEMPERATE OR DECIDUOUS FORESTS

- Temperate deciduous forests are a close relative of the Taiga biome
- They can be found in areas with a milder, shorter winter season.
- In addition to evergreens, trees in the temperate forest include maple, elm, oak, cedar, and other trees that shed their leaves in the fall.
- The temperate forest's soil in richer than that of the boreal forests and features a larger assortment of forest floor plant life
- This is due to the fact that the forests' canopy is thinner, allowing more light and heat to penetrate, permitting photosynthesis in the forest floor plants
- The survival of smaller, and cold-blooded animals such as garter snakes, turtles, and a few amphibians depends on different adaptations. Again, several of the temperate forests' species hibernate, and/or burrow in the ground to pass the winter months.

Climate Characteristics

- Temperature varies from -30° C to 30° C.
- The average temperature of the forest is about 50 degrees Fahrenheit.
- Precipitation (75-150 cm) is distributed evenly throughout the year.
- The average rainfall in the forest is 30 to 60 inches a year
- Soil is fertile, enriched with decaying litter.
- Canopy is moderately dense and allows light to penetrate, resulting in well-developed and richly diversified understory vegetation and stratification of animals
- The deciduous trees lose their leaves in fall with spectacular fall colors, and they grow back in spring

Layers of the Temperate Deciduous Forest

- **Tree stratum (Canopy)** - the tallest layer, 60 -100 feet high, with large oak, maple, beech, chestnut, hickory, elm, basswood, linden, walnut, or sweet gum trees.
- **Small tree (Sapling Layer or Understory)** - short tree species and young trees.
- **Shrub layer** - shrubs like rhododendrons, azaleas, mountain laurels, and huckleberries.
- **Herb layer** - short plants.
- **Ground layer (Forest Floor)** - lichens, clubmosses, and true mosses.

The **Temperate Deciduous Forest** biome has **four seasons** of winter, spring, summer, and fall. Animals and plants have special adaptations to cope with these yearly changes.

Deciduous trees are trees that shed their leaves once a year at the approach of a cold or dry season and later grow new leaves. (Plants that keep their foliage throughout the year are called evergreens.)

Plant adaptations

Deciduous trees usually have broad leaves e.g., ash, beech, birch, maple, and oak.

- Flora is characterized by 3-4 tree species per square kilometer.
- Trees are distinguished by broad leaves that are lost annually and include such species as oak, hickory, beech, hemlock, maple, basswood, cottonwood, elm, willow, and spring-flowering herbs.
- In SUMMER, their broad green leaves help capture sunlight needed to make food through photosynthesis.
- As temperatures drop, the tree cuts off the supply of water to the leaves and seals off the area between the leaf stem and the tree trunk. With limited sunlight and water, the leaves are unable to continue producing chlorophyll (green pigment in leaves), causing them to change into the beautiful red, yellow, and orange leaf colors of fall
- In WINTER, it is too cold for the trees to protect their leaves from freezing, so they simply lose them and seal up the places where the leaves attach to the branch. Losing their leaves helps trees to conserve water loss through transpiration. (Dried leaves continue to hang on the branches of some deciduous trees until the new leaves come out.)

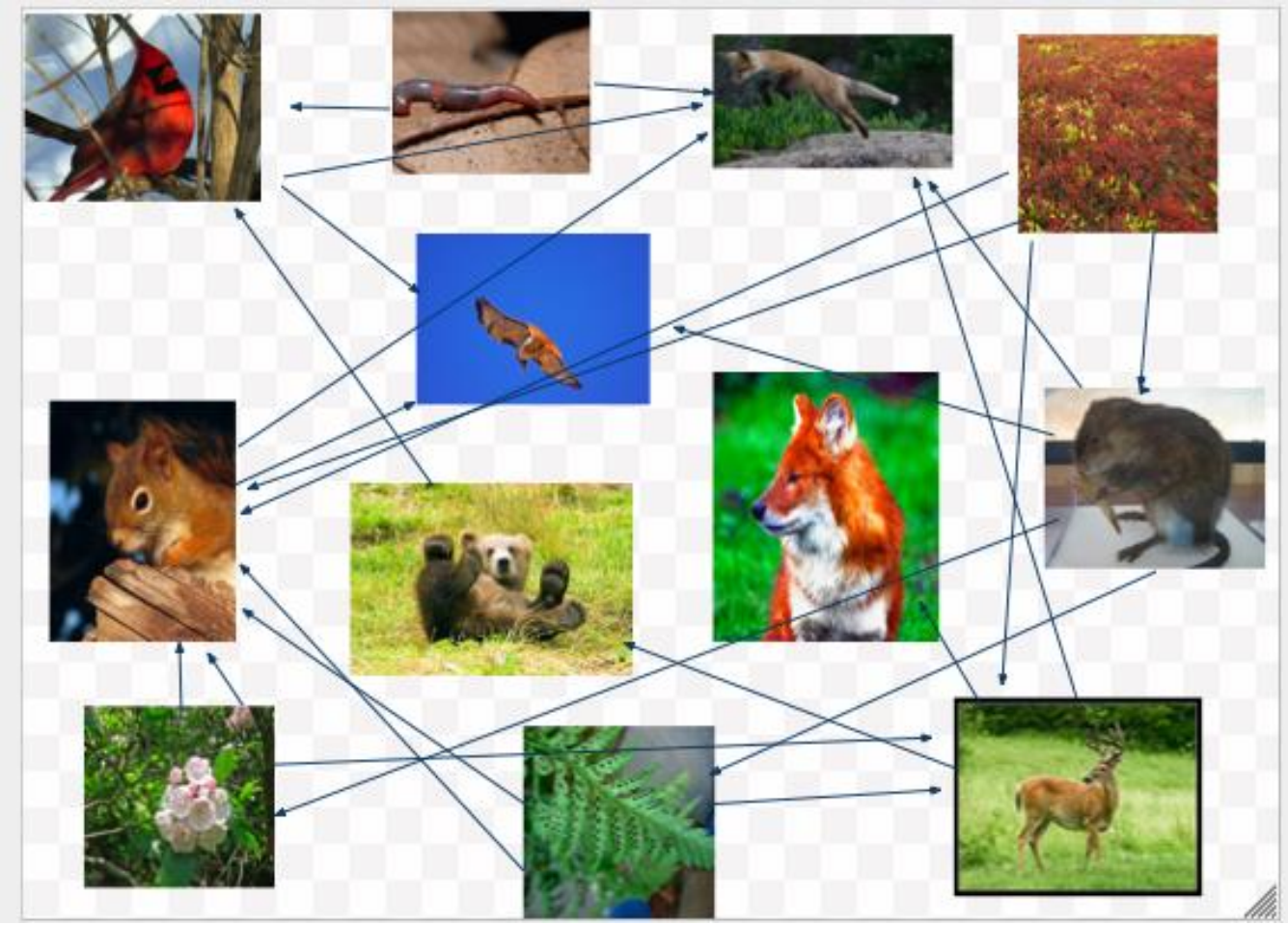
  Before the leaves die, some of the food material they contain is drawn back into the twigs and branches where it is stored and used the following spring.
- The warmer temperatures of SPRING signal to the trees that they can grow new leaves again and restart the cycle.

Animal adaptations

Animals in temperate deciduous forests also have to adapt to the changing seasons. They must be able to cope with cold winters when food is in short supply. Migration and hibernation are two adaptations used by the animals in this biome.

- Typical animals are squirrels, rabbits, skunks, birds, deer, mountain lions, bobcats, timber wolves, foxes, and black bears
- A great variety of birds migrate to warmer places where they can find food more easily.
- Some mammals (e.g., bears) hibernate during the cold winter months.
- Hibernation is an inactive, sleeplike state that some animals enter during the winter. Animals that hibernate protect themselves against the cold and reduce their need for food. A hibernating animal's body temperature is lower than normal, and its heartbeat and breathing slows down greatly. An animal in this state needs little energy to stay alive and can live off fat stored in its body. Thus, hibernating animals can more easily survive the cold winter months.
- Squirrels, chipmunks, and some jays often store large supplies of food (such as nuts and seeds) in the ground, under fallen leaves, or in tree hollows for use during the cold winters when food is scarce. Cold temperatures help prevent the decomposition of the nuts and seeds

DECIDUOUS FOREST FOOD WEB



Environmental Concerns

- Many of the world's great tracts of temperate deciduous forest have experienced significant alteration through logging, conversion to agricultural land, and urban development.
- Human industry within and adjacent to temperate deciduous forests may pollute air and water resources.
- Species introduced to temperate deciduous forests by humans may become invasive and threaten native ecological systems.

Biodiversity

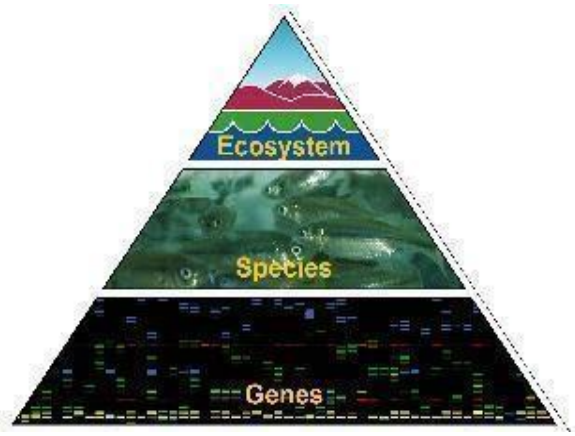
Biodiversity- *"variability among living organisms"*

- The term Biodiversity is coined by **Walter Rosen**, 1985
- It is the number of different organisms & their relative frequency in an ecosystem
- Biodiversity also includes: **Variability of genus, Variability of varieties, Variability of species, Variability of populations in different ecosystems, Variability in relative abundance of species**
- About 50 million species of plants, animals & microbes are estimated to exist in the world
- Among this, only 2 million are identified so far
- Knowledge of biodiversity is essential for **sustainable utilization** of resources
- Biological resources provide us: **Nourishment, Clothing, House, Fuel, Medicine, and Revenue**

Importance of Biodiversity:

- Different species with different traits in an environment can support different functions in the ecosystem. Removal of just one of these species can eventually impact all other species because of the countless species interactions in an ecosystem.
- Many anticancer, antibiotic, and antifungal medicines that we use have ingredients that are derived from different bacteria, fungi, plants, and animal species. People also rely on the use of natural medicines, which come from a variety of species.
- Agriculture depends on diverse landscapes to promote processes such as pollination. Thus, biodiversity is important to maintain for human health and population growth.
- Some species have cultural importance to communities, and their preservation is important to maintain certain traditions.
- Intrinsic value – some people argue that biodiversity has intrinsic value, and that each species should have a right to exist, even if its existence is not obviously beneficial to humans.
- In some geographic regions, eco-tourism depends on the maintenance of biodiversity so that a community can have economic resources.
- Declines in certain species can lead to increased health hazards for humans. For example, coral reefs and mangrove forests protect coastal regions from strong waves and storms.
- Spending time in nature and having green spaces has been shown to improve both mental and physical health.

Levels of Biodiversity:



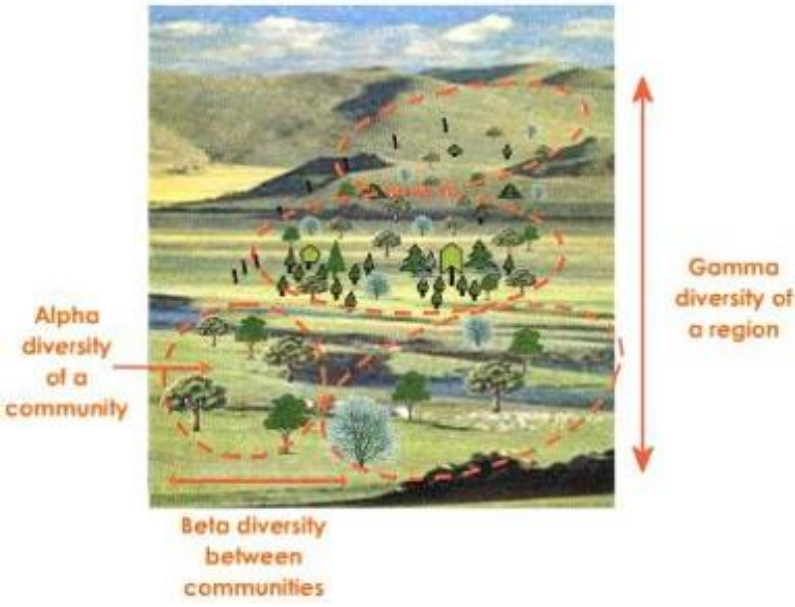
- **Genetic diversity** – varies in the genetic make-up among individuals within a single species
- **Species diversity** – variety among the species or distinct types of living organisms found in different habitats of the planet
- **Ecological diversity** – variety of forests, deserts, grasslands, streams, lakes, oceans, wetlands, and other biological communities. Variations in the community in which the species lives, the ecosystem in which the community exists, and interactions within and between biotic and abiotic components

Types of biodiversity: different types of biodiversity can be observed in nature

- **Genetic diversity:** diversity in the alleles of a single gene
- **Organismal diversity:** differences in morphology, anatomy, or behavior of organisms
- **Population diversity:** variations observed in quantitative ecological parameters such as frequency, density, abundance etc.
- **Species diversity:** Measures the variation in species numbers at a particular habitat
- **Community diversity:** variability among community composition of an ecosystem and variations in the ecological interactions
- **Ecosystem diversity:** deals with the variations of interdependence of biotic and abiotic factors in the ecosystem
- **Landscape diversity:** measures the species compositions in different landscapes
- **Biogeographic diversity:** diversity observed in geological and geographic history over a large period of time
- **Intraspecific Diversity:** diversity in the genomic and phenotypic traits found within and among populations
- **Functional Diversity:** variety and range of functional traits within a biological community or ecosystem

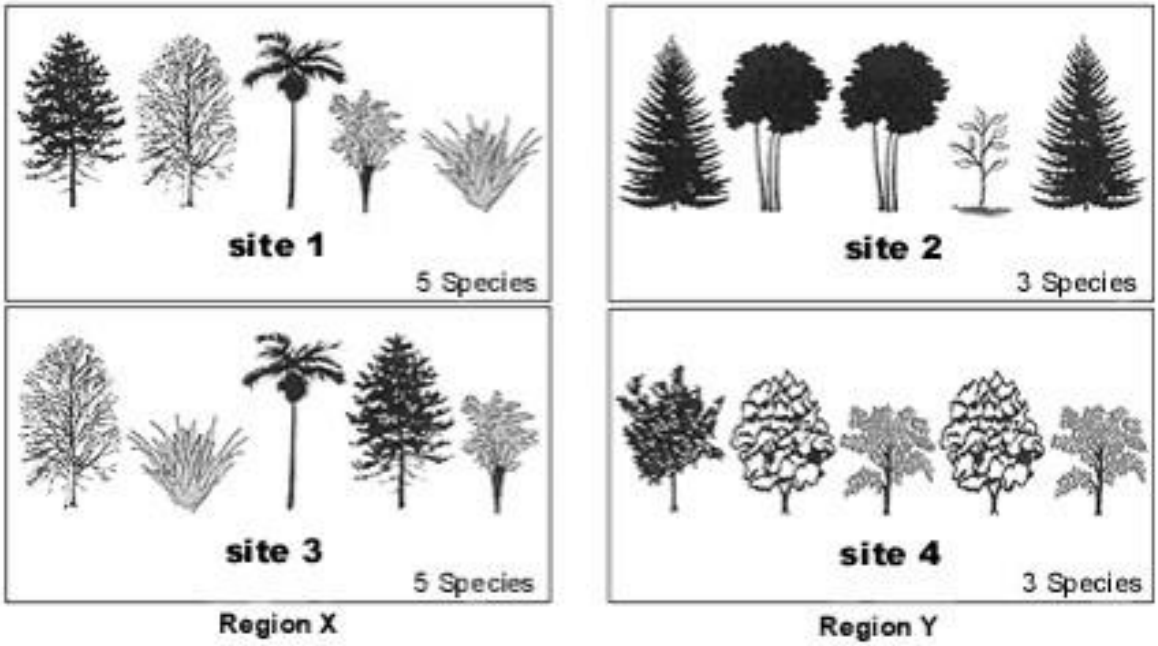
Species diversity and ecosystem stability

- higher diversity = higher stability
- In each ecosystem, there is a minimum threshold of species diversity needed to maintain stability. This threshold varies for each landscape depending on environmental factors.



Species Diversity Levels - Progress from local to regional levels

- ***Alpha*:** within habitat diversity - refers to a group of organisms interacting and competing for the same resources or sharing the same local environment. Measured as number of species within a given area.
- ***Beta*:** species diversity along transects & gradients - refers to the response of organisms to spatial heterogeneity. High beta-diversity implies low similarity between species composition of different habitats. It is usually expressed in terms of similarity index between communities (or species turnover rate) between different habitats in same geographical area (often expressed as some kind of gradient). High Beta indicates number of species increases rapidly with additional sampling sites along the gradient
- ***Gamma*:** diversity of a larger geographical unit (island) - Geographical diversity



ALPHA-, BETA- AND GAMMA-DIVERSITY.
Alpha diversity is measured locally, at a single site, as at sites 1 and 2. Site 1 has higher alpha-diversity than site 2.

Beta-diversity measures the amount of change betwen two sites or along a gradient, as in regions X and Y. Region Y has higher beta-diversity than region X, as there is a higher turnover of species among the sites in region Y.

Gamma-diversity is similar to alpha-diversity, only measured over a large scale. Both alpha- and beta-diversity contribute to gamma-diversity. Region X has high alpha-diversity at its sites, but they are all fairly similar; the region thus has low beta-diversity and only moderate gamma-diversity. Region Y has low alpha-diversity at its sites, but the sites differ from each other; the region therefore has high beta-diversity, and higher gamma-diversity than region X.

Measuring Biodiversity – Div. C

Biodiversity is defined and measured as an attribute that has two components — **richness** and **evenness**.

- **Richness** = The number of groups of genetically or functionally related individuals. In most vegetation surveys, richness is expressed as the number of species and is usually called **species richness**.
- **Evenness** = Proportions of species or functional groups present on a site. The more equal the proportions of species are to each other, the greater the evenness of the site. A site with low evenness indicates that a few species dominate the site.

The most common measures of biodiversity are species richness, Simpson's index, and Shannon's index. Although it's good to know what each test helps you understand, software programs have been designed to do the math for you. One example of a program for measuring biodiversity is **EstimateS**. The count of the species, coupled with these tests, summarizes most of the information on biodiversity.

- **Species richness:** This is the simplest measure of species diversity. Simply count the number of species found in your sample area. Since we expect to find more species if the larger the sample, we account for this bias by dividing the number of species by the square root of the number of individuals in the sample. This particular measure of species richness is known as D, the Menhinick's index.

$$D = \frac{s}{\sqrt{N}}$$

where s equals the number of different species represented in your sample and N equals the total number of individual organisms in your sample.

- **Species Diversity:** Species diversity differs from species richness in that it takes into account both the ***numbers of species*** present and the dominance or ***evenness of species*** in relation to one another. **Shannon-Wiener index is used.** Interestingly Shannon, a physicist, developed the index as a formula for measuring the entropy of matter in the universe. It turns out that the mathematical relationships hold true whether one is dealing with molecules in solution or species in an ecological community!

$$H = \sum (pl) |\ln pl|$$

Where (pl) is the proportion of the total number of individuals in the population that are in species "l" in the community.

- Should only be used on random samples taken from a large community where the total number of species is known.
  - Measures the order, or disorder, observed within a specific community.
  - Can be used to determine evenness, a measure of abundance similarity among the various species in the community.

Advantages and Disadvantages Shannon-Wiener's Index

- All species must be represented
- Relatively easy to calculate
- Sensitive to changes in rare species

Simpson's Index: The probability of picking two different organisms at random.

- **Simpson's Index** = D.

$$D = \frac{\Sigma n(n - 1)}{N(N - 1)}$$

where N = the total number of organisms of all species
n = the total number of organisms of a particular species.
The value of D ranges between 0 and 1. 0 represents infinite diversity and 1 represents no diversity

- **Simpson's Diversity Index** = 1 – D
- **Simpsons Reciprocal Index** = 1/D

Advantages and Disadvantages of Simpson's Index

- Aids in understanding the biodiversity across communities.
- Gives more attention to common species rather than rare species.
- Works very well with small samples.
- Does not require all species be represented
- Measures chance that two individuals are from same species
- Sensitive to changes in common species
- Weighted towards most abundant species
- Opposite of dominance

Biodiversity Calculator - http://www.alyoung.com/labs/biodiversity_calculator.html

DIV C - SEE THE HANDOUT ON BIODIVERSITY CALCULATIONS