ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 6

Species Interactions and Community Ecology

Part 1: Foundations of Environmental Science

PowerPoint® Slides prepared by
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This lecture will help you understand:

- Species interactions
- Feeding relationships, energy flow, trophic levels, and food webs
- Keystone species
- The process of succession
- Potential impacts of invasive species
- Ecological restoration
- Terrestrial biomes

Case Study: Black and white and spread all over

- Small, black and white shellfish
- Introduced to Lake St. Clair, Canada, in 1988, in discharged ballast water
- Within 2 years, the zebra mussels invaded all 5 Great Lakes
- Populations grew exponentially
  - No natural predators, competitors, or parasites
- Hundreds of millions of dollars of damage to property

(a) Clogging a pipe

Species interactions

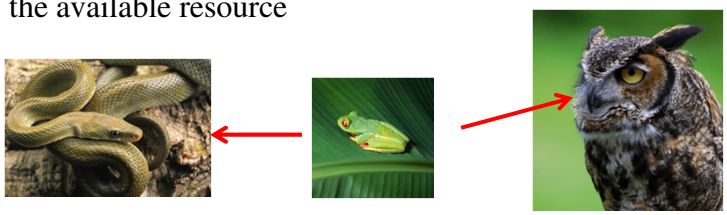
- Species interactions are the backbone of communities
- Most important categories
  - **Competition** = both species are harmed
  - **Predation, parasitism,** and **herbivory** = one species benefits and the other is harmed
  - **Mutualism** = both species benefit

Competition

- **Competition** = relationship where multiple organisms seek the same limited resources they need to survive:
  - Food - Water
  - Space - Shelter
  - Mates - Sunlight
- **Intraspecific competition** = between members of the same species
  - High population density = increased competition
- **Interspecific competition** = between members of 2 or more species
  - Leads to competitive exclusion or species coexistence

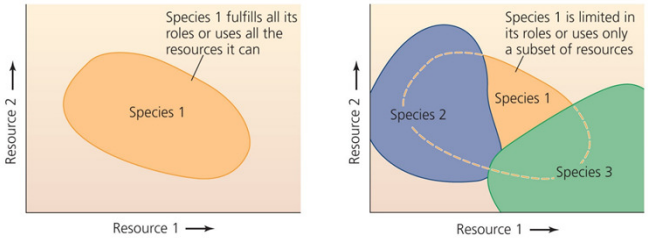
Results of interspecific competition

- **Competitive exclusion** = one species completely excludes another species from using the resource
- **Species coexistence** = neither species fully excludes the other from resources, so both live side by side
  - This produces a stable point of equilibrium, with stable population sizes
  - Species adjust to minimize competition by using only a part of the available resource



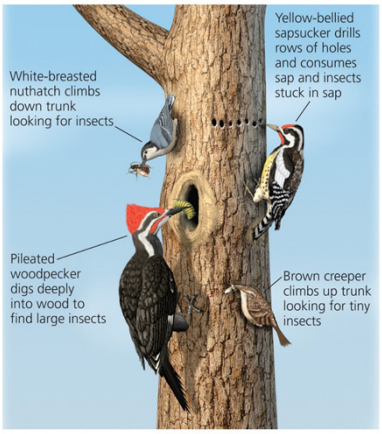
Niche: an individual's ecological role

- **Fundamental niche** = when an individual fulfills its entire role by using all the available resources
- **Realized niche** = the portion of the fundamental niche that is actually filled
  - Due to competition or other species' interactions



Resource partitioning

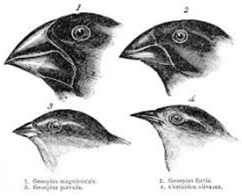
- **Resource partitioning** = when species divide shared resources by specializing in different ways
  - Ex: one species is active at night, another in the daytime
  - Ex: one species eats small seeds, another eats large seeds



Effects of resource partitioning

- **Character displacement** = competing species evolve physical characteristics that reflect their reliance on the portion of the resource they use
  - Ex: birds that eat larger seeds evolve larger bills
  - Ex: birds that eat smaller seeds evolve smaller bills

Competition is reduced when two species become more different



Predation

- **Exploitation** = one member exploits another for its own gain
  - Predation, parasitism, herbivory
- **Predation** = process by which individuals of one species (**predators**) capture, kill, and consume individuals of another species (**prey**)
  - Structures food webs
  - Influences community composition through number of predators and prey

Effects of zebra mussels

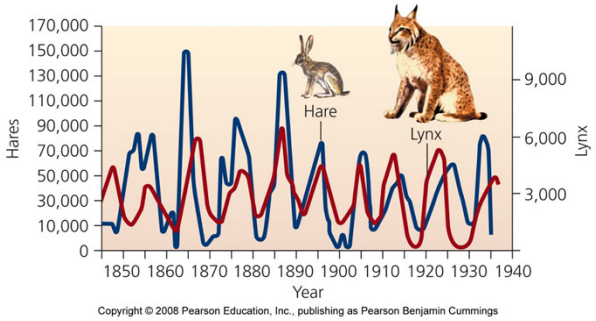


- Zebra mussels eat phytoplankton and zooplankton
  - Both populations decrease in lakes with zebra mussels
- They don't eat cyanobacteria
  - Population increases in lakes with zebra mussels

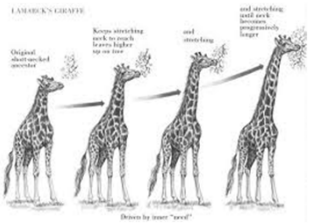
- Zebra mussels are becoming prey for some North American predators:
  - Diving ducks, muskrats, crayfish, flounder, sturgeon, eels, carp, and freshwater drum

Effects of predation on populations

- Increased prey populations increases predators
  - Predators survive and reproduce
- Increased predator populations decrease prey
- Decreased prey population causes starvation of predators
- Decreased predator populations increases prey populations



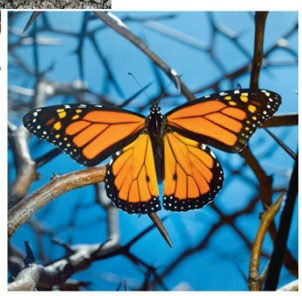
Natural selection



- Natural selection leads to evolution of adaptations that make predators better hunters
- Individuals who are better at catching prey:
  - Live longer, healthier lives
  - Take better care of offspring
- Predation pressure: prey are at risk of immediate death
  - Prey develops elaborate defenses against being eaten

Organisms evolve defenses against being eaten

(a) Cryptic coloration



(b) Warning coloration

(c) Mimicry

Parasites

- **Parasitism** = a relationship in which one organism (**parasite**) depends on another (**host**) for nourishment or other benefit
- Some species live within the host
  - Disease, tapeworms
- Others are free-living, and have infrequent contact with their hosts
  - Ticks, sea lampreys

Coevolution

- **Coevolution** = hosts and parasites become locked in a duel of escalating adaptations
  - Has been called an "evolutionary arms race"
  - Each evolves new responses to the other
  - It may not be beneficial to the parasite to kill its host

Herbivory

- Exploitation in which animals feed on the tissues of plants
  - Widely seen in insects
  - May not kill the plant, but affects its growth and survival
- Defenses against herbivory include
  - Chemicals: toxic or distasteful parts
  - Physical: thorns, spines, or irritating hairs
  - Other animals: protect the plant

Mutualism

- Two or more species benefit from their interactions
- **Symbiosis** = mutualism in which the organisms live in close physical contact
  - Microbes within digestive tracts
  - Plants and fungi
- **Pollination** = bees, bats, birds and others transfer pollen from one flower to another, fertilizing its eggs

Pollination

In exchange for the plant nectar, the animals pollinate plants, which allows them to reproduce

Relationships with no effect on one member

- **Amensalism** = a relationship in which one organism is harmed while the other is unaffected
  - Difficult to confirm, because usually one organism benefits from harming another
  - **Allelopathy** = certain plants release harmful chemicals
  - Or, is this competition?

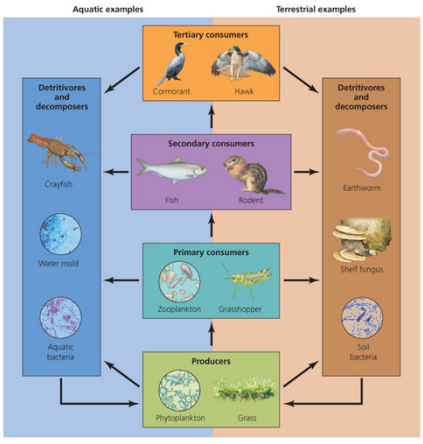
- **Commensalism** = a relationship in which one organism benefits, while the other remains unaffected
  - **Facilitation** = plants that create shade and leaf litter allow seedlings to grow

Ecological communities

- **Community** = an assemblage of species living in the same place at the same time
  - Members interact with each other
  - Interactions determine the structure, function, and species composition of the community
- **Community ecologists** = people interested in how:
  - Species coexist and relate to one another
  - Communities change, and why patterns exist

Energy passes through trophic levels

- One of the most important species interactions is who eats whom
- Matter and energy move through the community
- **Trophic levels** = rank in the feeding hierarchy
  - Producers
  - Consumers
  - Detritivores and Decomposers



Producers: the first trophic level

- **Autotrophs** ("self-feeders") = organisms that capture solar energy for photosynthesis to produce sugars
  - Green Plants
  - Cyanobacteria
  - Algae
- **Chemosynthetic bacteria** use the geothermal energy in hot springs or deep-sea vents to produce their food

Consumers: organisms that consume producers

Primary consumers = second trophic level
- Organisms that consume producers
- **Herbivores** consume plants
- Deer, grasshoppers

- **Secondary consumers** = third trophic level
  - Organisms that prey on primary consumers
  - **Carnivores** consume meat
  - Wolves, rodents

Consumers occur at even higher trophic levels

- **Tertiary Consumers** = fourth trophic level
  - Predators at the highest trophic level
  - Consume secondary consumers
  - Are also carnivores
  - Hawks, owls
- **Omnivores** = consumers that eat both plants and animals

Detritivores and decomposers

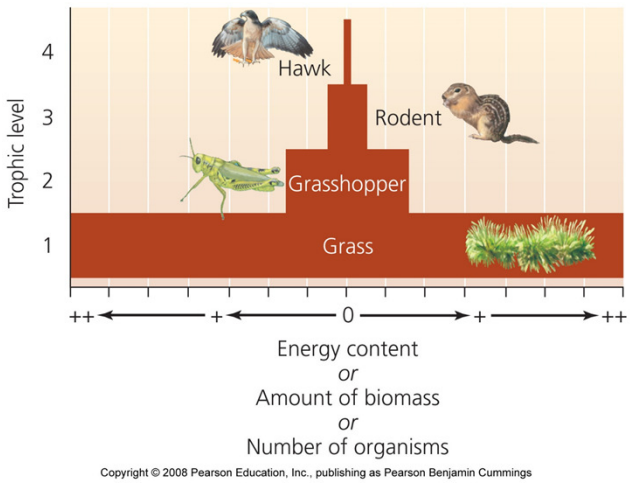
- Organisms that consume nonliving organic matter
  - Enrich soils and/or recycle nutrients found in dead organisms
- **Detritivores** = scavenge waste products or dead bodies
  - Millipedes
- **Decomposers** = break down leaf litter and other non-living material
  - Fungi, bacteria
  - Enhance topsoil and recycle nutrients

Energy, biomass, and numbers decrease

- Most energy organisms use is lost as waste heat through respiration
  - Less and less energy is available in each successive trophic level
  - Each level contains only 10% of the energy of the trophic level below it
- There are far fewer organisms at the highest trophic levels, with less energy available

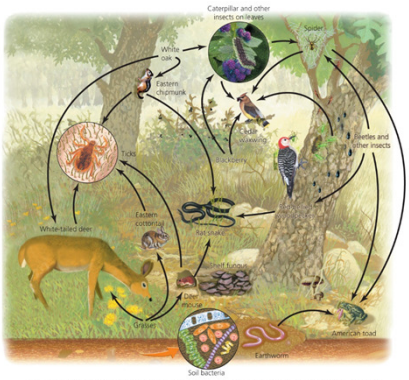
A human vegetarian's ecological footprint is smaller than a meat-eater's footprint

Pyramids of energy, biomass, and numbers



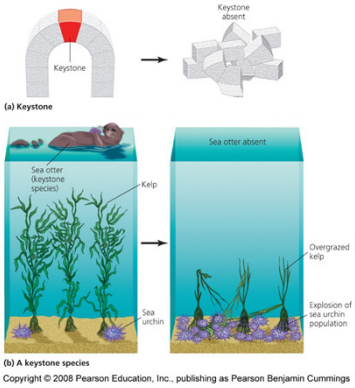
Food webs show relationships and energy flow

- **Food chain** = the relationship of how energy is transferred up the trophic levels
- **Food web** = a visual map of feeding relationships and energy flow
  - Includes many different organisms at all the various levels
  - Greatly simplified; leaves out the majority of species



Some organisms play big roles

- **Keystone Species** = has a strong or wide-reaching impact far out of proportion to its abundance
- Removal of a keystone species has substantial ripple effects
  - Alters the food chain



Species can change communities

- **Trophic Cascade** = predators at *high trophic levels* can indirectly affect populations of organisms at *low trophic levels* by keeping species at *intermediate trophic* levels in check
  - Extermination of wolves led to increased deer populations, which led to overgrazed vegetation and changed forest structure
- Ecosystem engineers = physically modify the environment
  - Beaver dams, prairie dogs, fungi

Communities respond to disturbances

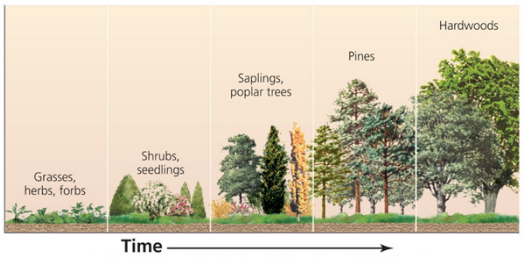
- Communities experience many types of disturbance
  - Removal of keystone species, spread of invasive species, natural disturbances
  - Human impacts cause major changes
- **Resistance** = community of organisms resists change and remains stable despite the disturbance
- **Resilience** = a community changes in response to a disturbance, but later returns to its original state

Primary succession

- **Succession** = the predictable series of changes in a community following a disturbance
- **Primary succession** = disturbance eliminates all vegetation and/or soil life
  - Glaciers, drying lakes, volcanic lava
- **Pioneer species** = the first species to arrive in a primary succession area (ex, lichens)

Secondary succession

- **Secondary succession** = a disturbance dramatically alters, but does not destroy, all local organisms
  - The remaining organisms form "building blocks" for the next population species
  - Fires, hurricanes, farming, logging
- **Climax community** = the community resulting from successful succession
  - Remains stable until another disturbance restarts succession



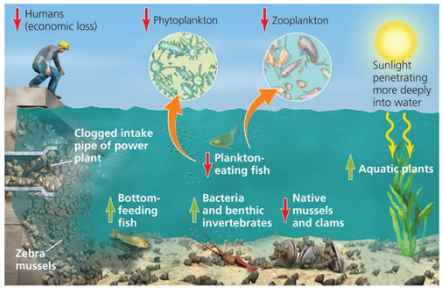
Community cohesion

- **Frederick Clements** = viewed communities as cohesive entities
  - Its members remain associated over space and time
  - The community shared similar limiting factors and evolutionary histories
- **Henry Gleason** = maintained that each species responds independently to its own limiting factors
  - Species can join or leave communities without greatly altering the community's composition
  - The most widely accepted view of ecologists today

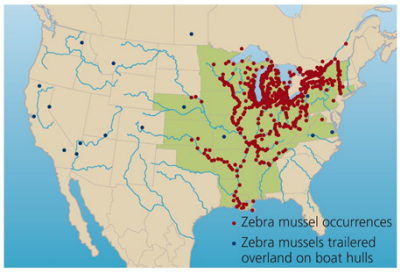
Invasive species

- **Invasive species** = non-native (exotic) organisms that spread widely and become dominant in a community
  - Growth-limiting factors (predators, disease, etc.) are removed or absent
  - They have major ecological effects
  - Chestnut blight, from Asia, wiped out American chestnut trees
- Some species help people (i.e., European honeybee)

Two invasive mussels



(a) Impacts of zebra mussels on members of a Great Lakes nearshore community



(b) Occurrence of zebra mussels in North America, 2005

(c) Occurrence of quagga mussels in North America, 2007

Controlling invasive species

- Techniques to control invasive species
  - Remove manually
  - Toxic chemicals
  - Drying them out
  - Depriving of oxygen
  - Stressing them
    - Heat, sound, electricity, carbon dioxide, ultraviolet light

Prevention, rather than control, is the best policy

Changed communities need to be restored

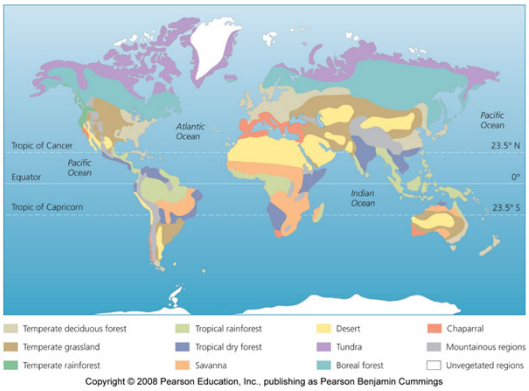
- **Ecological restoration** = returning an area to unchanged conditions
  - Informed by restoration ecology = the science of restoring an area to the condition that existed before humans changed it
  - It is difficult, time-consuming, expensive
  - Best to protect natural systems from degradation in the first place

Restoration efforts

- Prairie Restoration
  - Native species replanted and invasive species controlled
- The world's largest project: Florida Everglades
  - Depletion caused by flood control practices and irrigation
  - Populations of wading birds dropped 90-95%
  - It will take 30 years, and billions of dollars
- The U.S. is trying to restore Iraq marshes

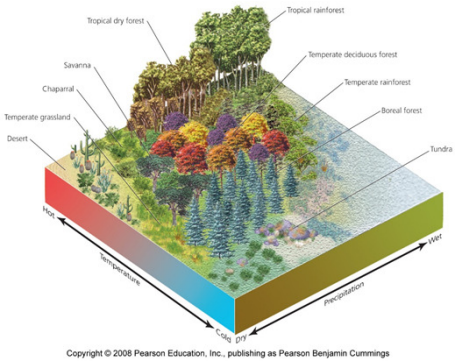
Widely separated regions share similarities

- Biome = major regional complex of similar communities recognized by
  - Plant type
  - Vegetation structure



A variety of factors determine the biome

- The biome in an area depends on a variety of abiotic factors
  - Temperature, precipitation, atmospheric circulation, soil
- Climatographs
  - A climate diagram showing an area's mean monthly temperature and precipitation
  - Similar biomes occupy similar latitudes



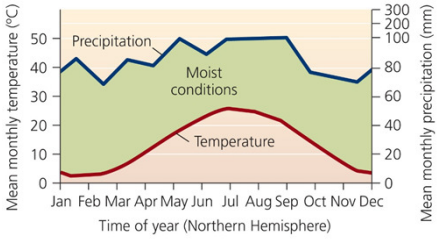
Aquatic systems have biome-like patterns

- Various aquatic systems comprise distinct communities
  - Coastlines, continental shelves
  - Open ocean, deep sea
  - Coral reefs, kelp forests
- Aquatic systems are shaped by
  - Water temperature, salinity, and dissolved nutrients
  - Wave action, currents, depth
  - Substrate type, and animal and plant life

Temperate deciduous forest

- **Deciduous trees** lose their leaves each fall and remain dormant during winter
- Mid-latitude forests in Europe, East China, Eastern North America
- Fertile soils
- Forests = oak, beech, maple

(a) Temperate deciduous forest

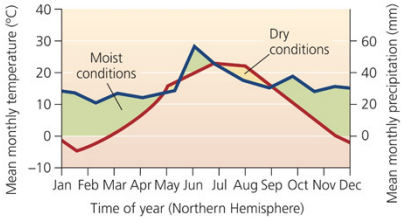


(b) Washington, D.C., USA

Temperate grasslands

- More extreme temperature difference between winter and summer
- Less precipitation
- Also called **steppe** or **prairie**
  - Once widespread throughout parts of North and South America and much of central Asia
  - Much was converted for agriculture
  - Bison, prairie dogs, antelope, and ground-nesting birds

(a) Temperate grassland

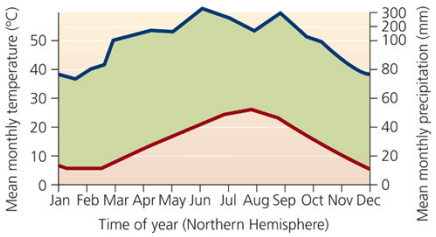


(b) Odessa, Ukraine

Temperate rainforest

- Coastal Pacific Northwest region
- Great deal of precipitation
- Coniferous trees: cedar, spruce, hemlock, fir
- Moisture-loving animals
  - Banana slug
- The fertile soil is susceptible to erosion and landslides
- Provides lumber and paper

(a) Temperate rainforest

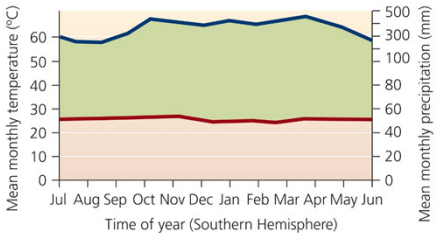


(b) Nagasaki, Japan

Tropical rainforest

- Central America, South America, southeast Asia, and west Africa
- Year-round rain and warm temperatures
- Dark and damp
- Lush vegetation
- Variety of animals and tree species, but in low numbers
- Very poor, acidic soils

(a) Tropical rainforest

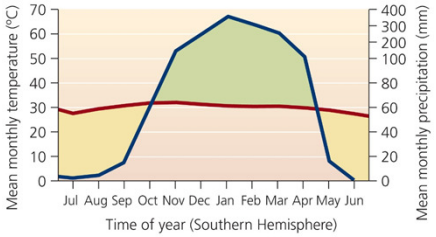


(b) Bogor, Java, Indonesia

Tropical dry forest

- Tropical deciduous forest
- India, Africa, South America, northern Australia
- Wet and dry seasons
- Warm, but less rainfall
- Converted to agriculture
- Erosion-prone soil

(a) Tropical dry forest

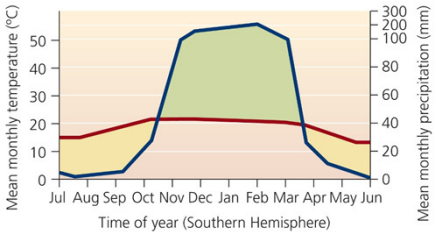


(b) Darwin, Australia

Savanna

- Grassland interspersed with trees
- Africa, South America, Australia, India
- Precipitation only during rainy season
- Water holes
- Zebras, gazelles, giraffes, lions, hyenas

(a) Savanna

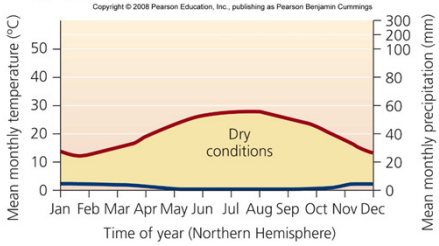


(b) Harare, Zimbabwe

Desert

- Minimal precipitation
- Some deserts are bare, with sand dunes (Sahara)
- Some deserts are heavily vegetated (Sonoran)
- They are not always hot
  - Temperatures vary widely
- Saline soils
- Nocturnal or nomadic animals
- Plants have thick skins or spines

(a) Desert

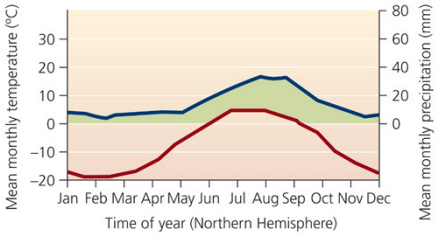


(b) Cairo, Egypt

Tundra

- Canada, Scandinavia, Russia
- Minimal precipitation
  - Nearly as dry as a desert
- Seasonal variation in temperature
  - Extremely cold winters
- Permafrost: permanently frozen soil
- Few animals: polar bears, musk oxen, caribou
- Lichens and low vegetation with few trees

(a) Tundra

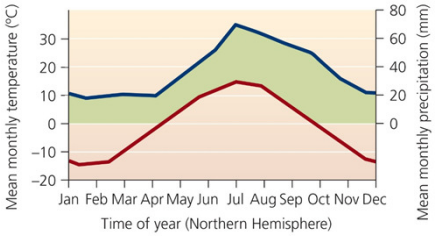


(b) Vaigach, Russia

Boreal forest (taiga)

- Canada, Alaska, Russia, Scandinavia
- Variation in temperature and precipitation
- Cool and dry climate
  - Long, cold winters
  - Short, cool summers
- Poor and acidic soil
- Few evergreen tree species
- Moose, wolves, bears, migratory birds

(a) Boreal forest

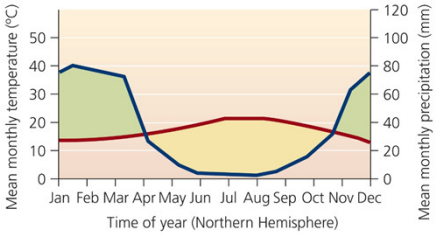


(b) Archangelsk, Russia

Chaparral

- Mediterranean Sea, California, Chile, and southern Australia
- High seasonal
  - Mild, wet winters
  - Warm, dry summers
- Frequent fires
- Densely thicketed, evergreen shrubs

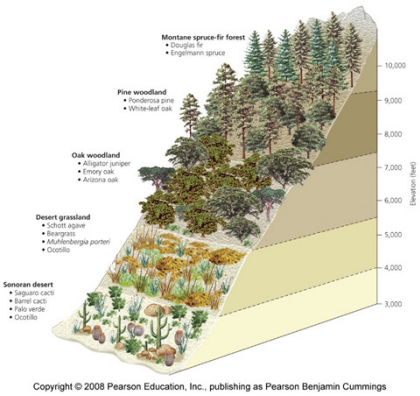
(a) Chaparral



(b) Los Angeles, California, USA

Altitudes create patterns

- Vegetative communities change along mountain slopes
  - In the Andes, a mountain climber would begin in the tropics and end up in a glacier



Hiking up a mountain in the southwest U.S. is analogous to walking from Mexico to Canada

Conclusion

- Biomes and communities help us understand how the world functions and how
- Species interactions affect communities
  - Predation, parasitism, competition, mutualism
- Humans have altered many communities
- Ecological restoration attempts to undo the negative changes that we have caused