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5

Ecosystems and Living Organisms

Overview of Chapter 5

- Evolution: How Populations Change Over Time
- Principles of Population Ecology
- Biological Communities
- Species Richness in a Community
- Community Development

Yellowstone and gray wolves

- Wolves are a top predator, were near extinction, listed endangered in 1974
- Reintroduced into Yellowstone 1995 by FWS
- Wolves are having far reaching effects on ecosystems
  - Wolves prey on elk, less overgrazing, greater biodiversity of plants and small predators, reduced coyote and increased scavenger populations


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Evolution

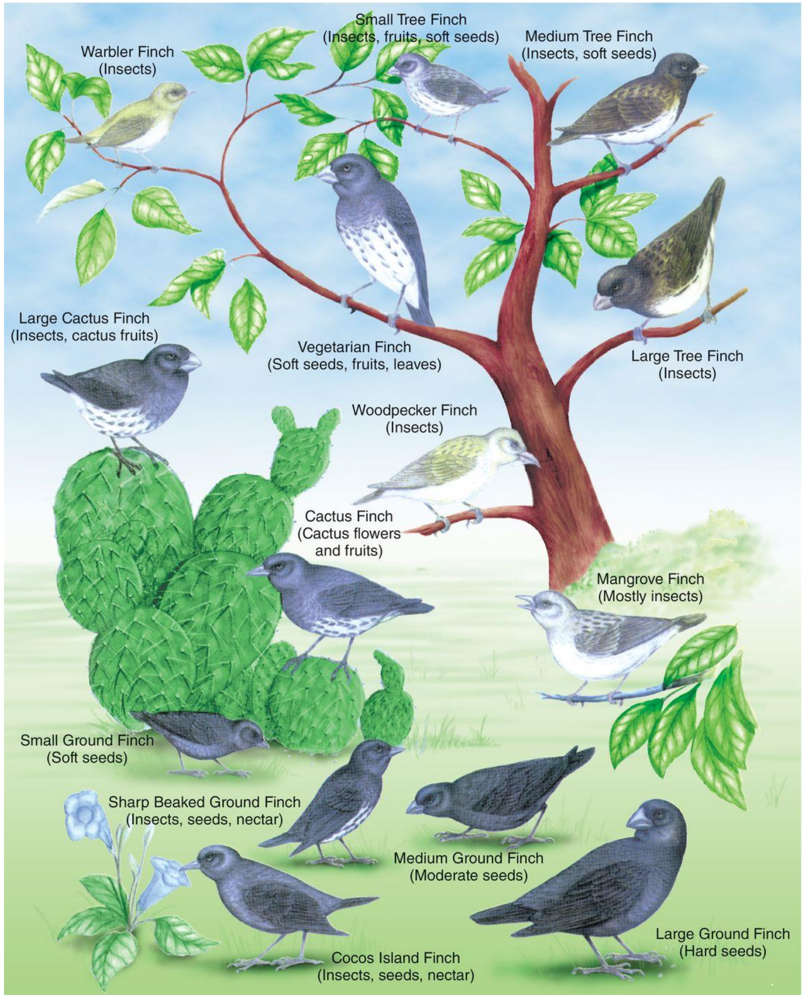
- The cumulative genetic changes that occur in a population of organisms over time
  - Current theories proposed by Charles Darwin, a 19th century naturalist
  - Occurs through natural selection
- Natural Selection
  - Individuals with more favorable genetic traits are more likely to survive and reproduce
  - Frequency of favorable traits increase in subsequent generations (adaptation)

Natural Selection

- Based on four observations about the natural world:
  1. High Reproductive Capacity
     - Produce more offspring than will survive to maturity
  2. Heritable Variation
     - Individuals vary in traits that may impact survival
  3. Limits on Population Growth, or a Struggle For Existence
     - Outside pressure on which individuals will survive
  4. Differential Reproductive Success
     - Best-adapted individuals reproduce more successfully than less adapted individuals

Natural Selection

- Darwin’s finches exemplified the variation associated with natural selection

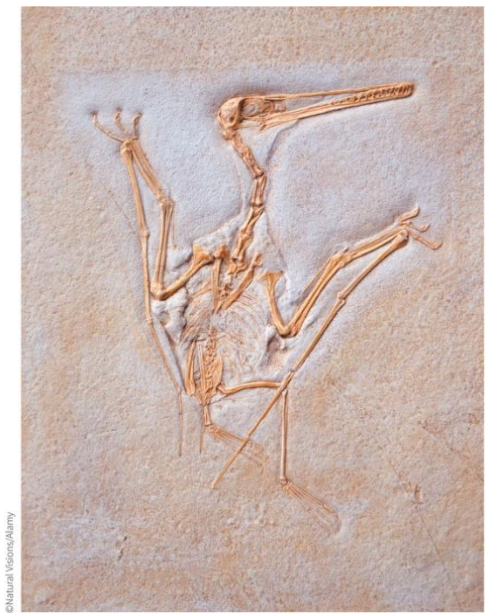


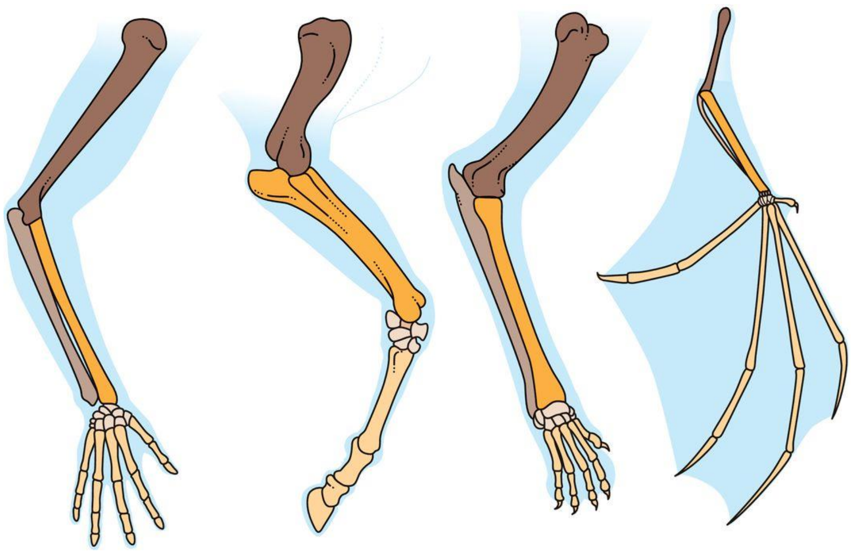
Modern Synthesis

- Combined natural selection with modern understanding of genetics for unified explanation
  - Includes research in fossils, developmental biology, classification, ecology, biogeography
- Explains with mutations (changes in DNA)
  - Genetic variability
  - Mutations can be beneficial, harmful, or of little impact
  - Chosen for or against

Modern Synthesis

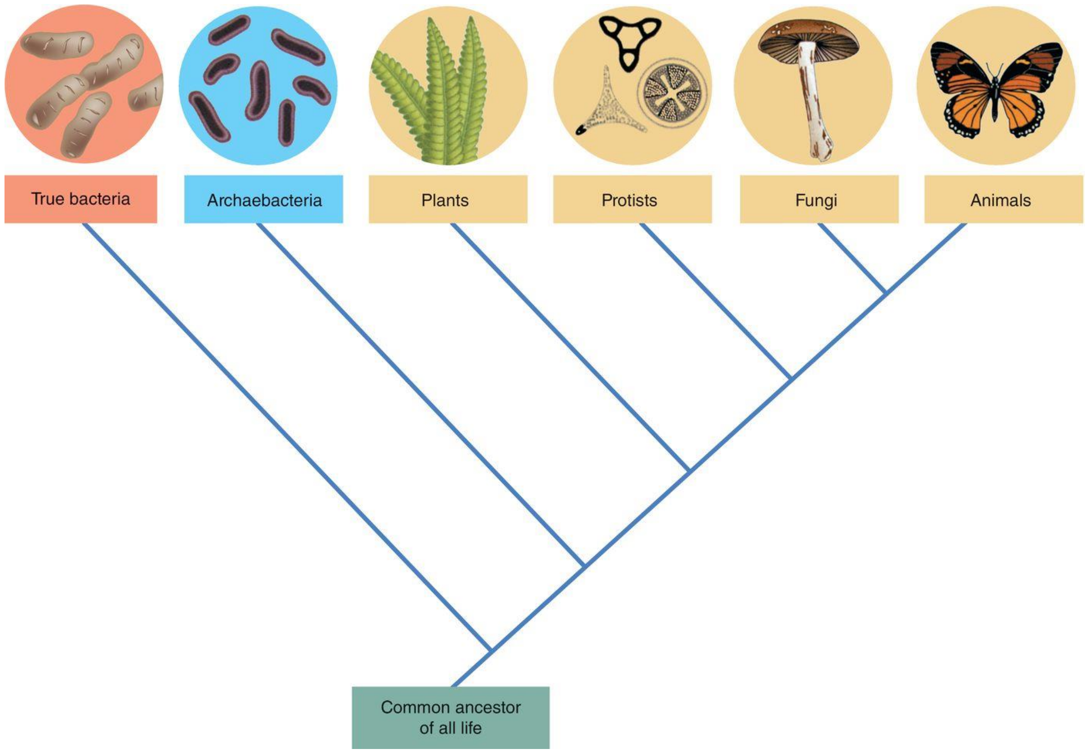
- Similarities of bone structure in fossils demonstrate relationships





Domains of Life

- We can trace similarities and make a ‘family tree’ of all organisms
- Can change with new knowledge



Domains of Life

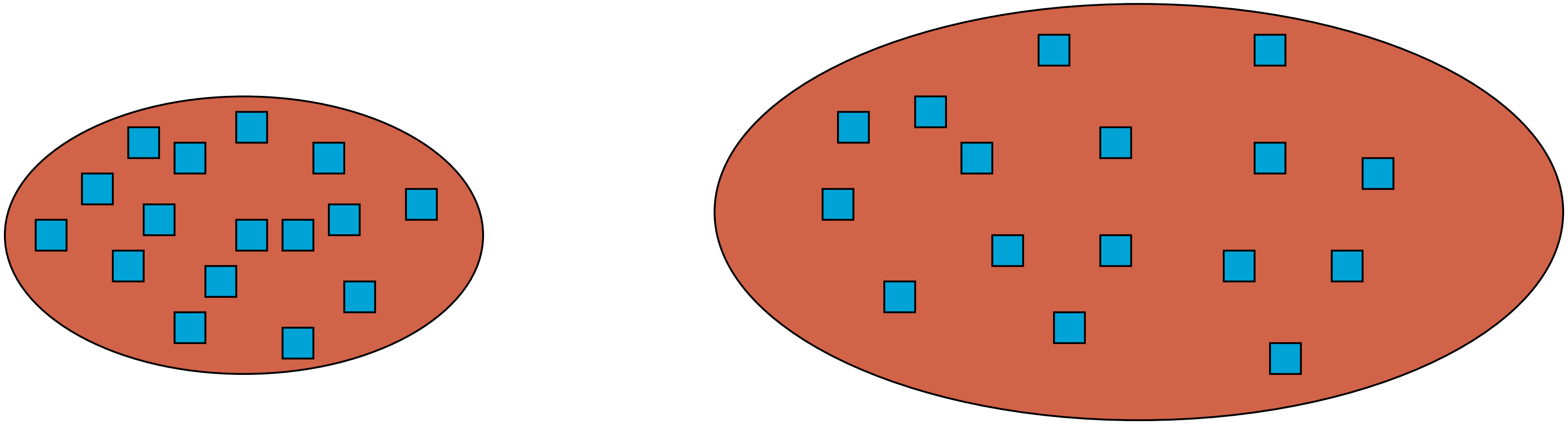
- Many relationships among organisms
- Theories
  - Chloroplasts and mitochondria were separate organisms in mutualistic relationship with cells?
  - Emerging knowledge about human digestion and gut bacteria

Principles of Population Ecology

- Population Ecology
  - Study of populations and how and why numbers change over time
  - Important for
    - Endangered species
    - Invasive species
    - Proper management (ex: deer)
- Population
  - Group of individuals of same species living in the same geographic area at the same time

Population Density

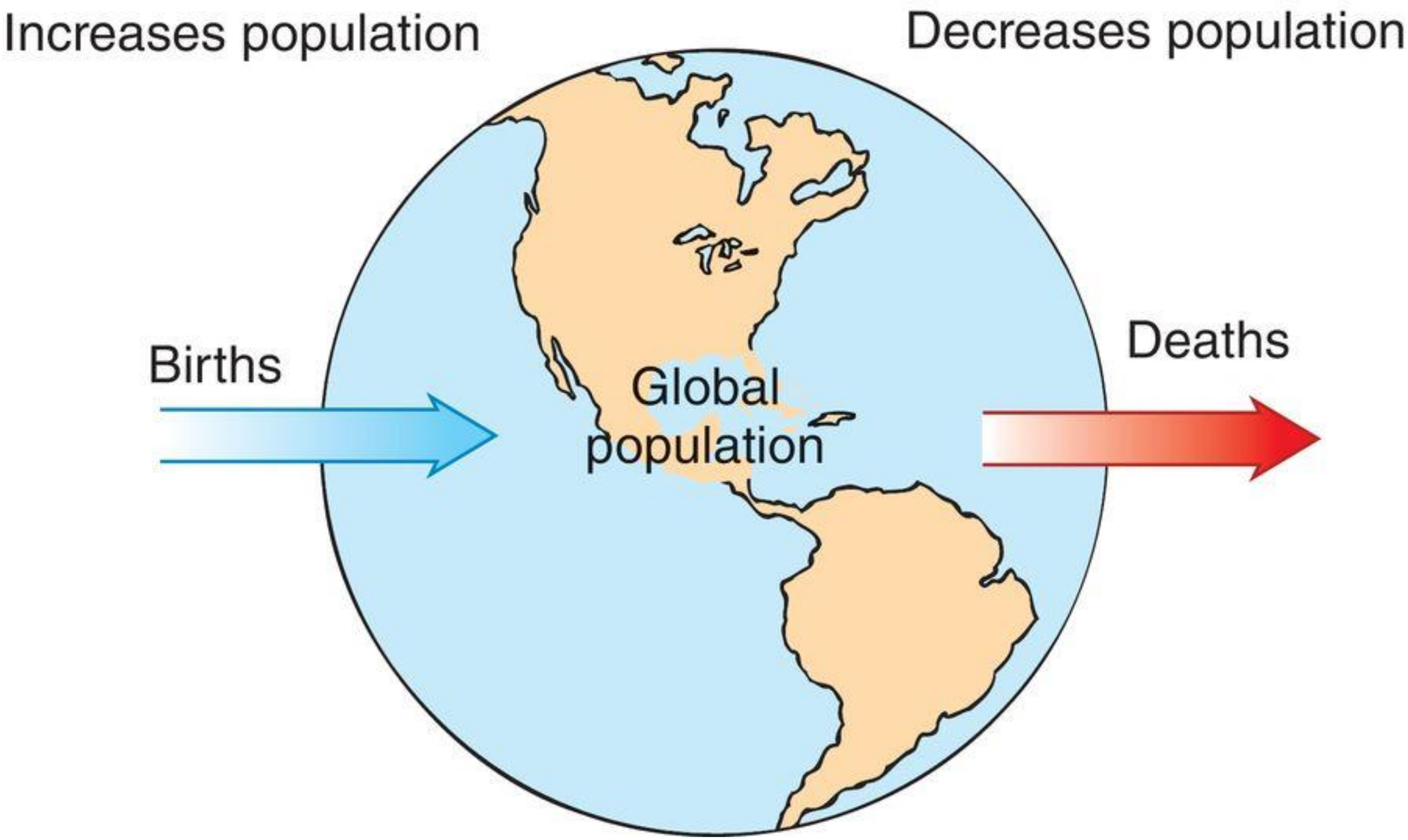
- Population density
  - The number of individuals of a species per unit area or volume at a given time
  - Ex: minnows per liter of pond water
- Ovals below have same population, and different densities



Growth Rate

- The rate of change of a population's size, expressed as percent per year
  - ***r* = *b* − *d***
  - *r* = growth rate, *b* = births/1000 people, *d* = deaths/1000 people
- Ex: A hypothetical human population has10,000 people, and 200 births per year (20 births per 1000 people) and 100 deaths per year (10 deaths per 1000 people)
  - ***r = (20 / 1000) – (10 / 1000)***
  - ***r = 0.02 − 0.01 = 0.01, or 1% per year increase***

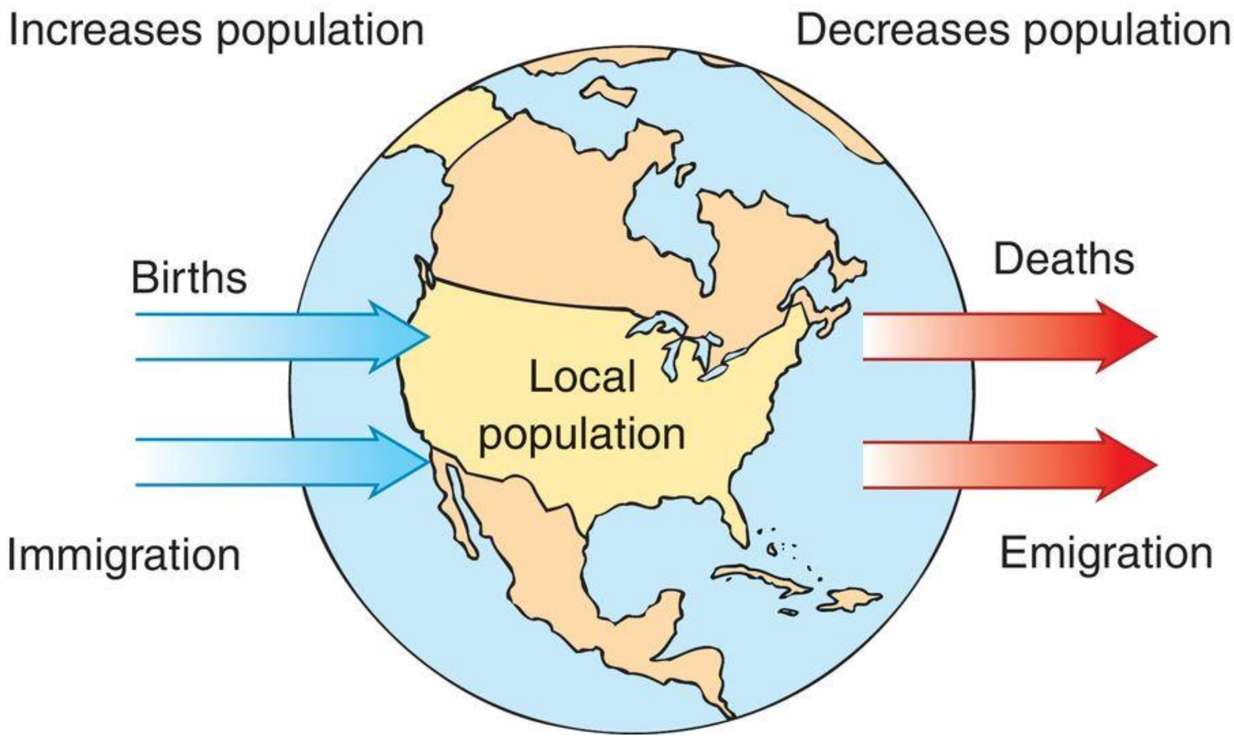
Change in Population Size



Growth Rate

- Can include dispersal in equation
  - movement of individuals in or out of area
- Dispersal important for
  - Population management
  - Dispersal of genes

Change in Population Size



In local populations, such as the population of the United States, the number of births, deaths, immigrants, and emigrants affects population size.

Calculating Population Change

Growth rate — Death rate — Emigration rate

$$r = (b - d) + (i - e)$$

Birth rate — Immigration rate

Birth (*b*), Death (*d*), Immigration (*i*) and Emigration (*e*) are calculated per 1000 people

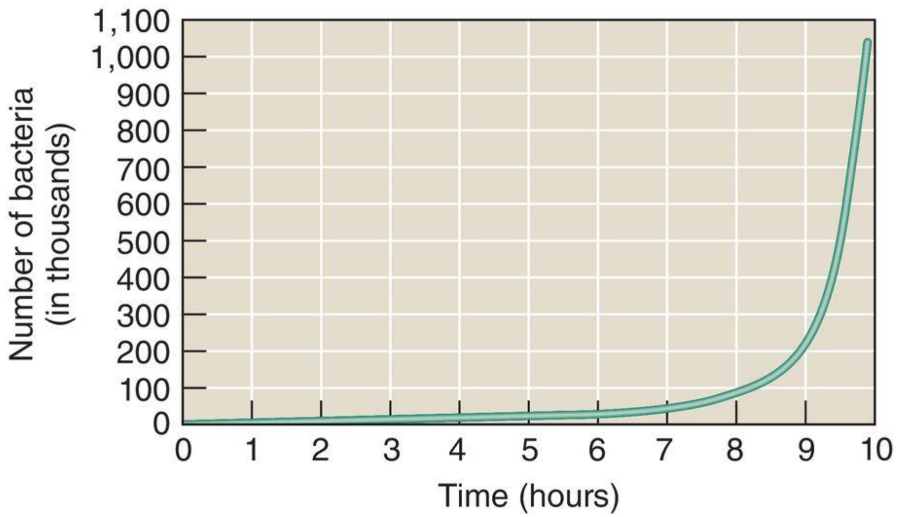
Maximum Population Growth

- Intrinsic Rate of Growth (Biotic Potential)
  - Growth rate under ideal conditions, exponential
  - J- Shaped Curve
- Each species has own based on life history characteristics
  - Age of onset of reproduction
  - Fraction of lifespan for reproduction
  - # of reproductive periods
  - # of offspring per reproductive period

Maximum Population Growth

Time (hours)	Number of bacteria
0	1
0.5	2
1.0	4
1.5	8
2.0	16
2.5	32
3.0	64
3.5	128
4.0	256
4.5	512
5.0	1,024
5.5	2,048
6.0	4,096
6.5	8,192
7.0	16,384
7.5	32,768
8.0	65,536
8.5	131,072
9.0	262,144
9.5	524,288
10.0	1,048,576

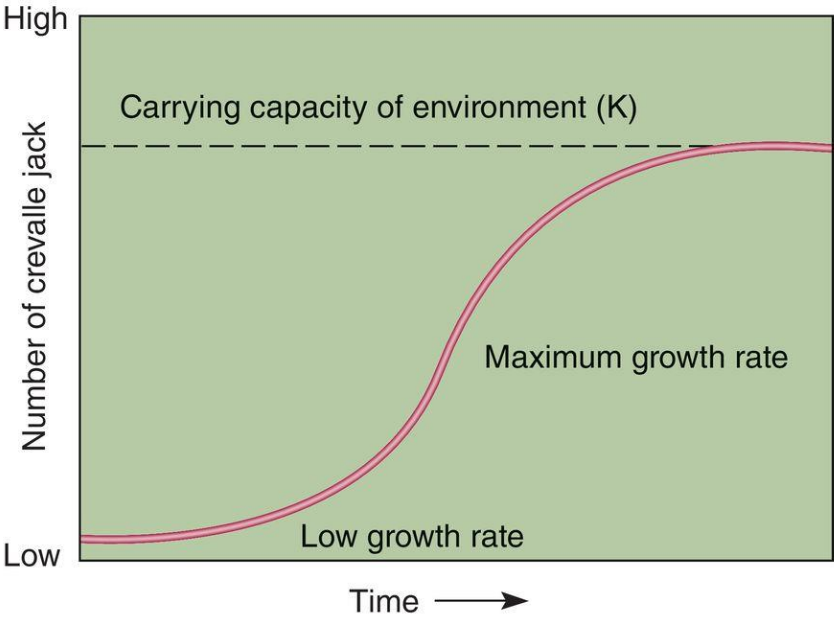
- Larger organisms, smaller rates
- Smaller organisms, faster reproduction, larger intrinsic rates of increase



Environmental Resistance

- Environmental limits (resistance to intrinsic growth)
  - Prevent indefinite reproduction
  - Unfavorable food, water, shelter, predation, etc.
- Negative feedback mechanism
  - Change in condition triggers response that reverses condition
- Carrying Capacity (*K*)
  - Maximum # of individuals an environment can support
  - Causes leveling off of exponential growth
  - S- shaped curve of logistic population growth

Carrying capacity



- Logistic population growth – S shape
  - More realistic than exponential
  - Very useful for management
  - Rarely stabilizes, bounces up and down

Population Crash

- Overshooting carrying capacity can lead to population crash
  - Abrupt decline in population density
  - Ex: reindeer dependent on winter forage

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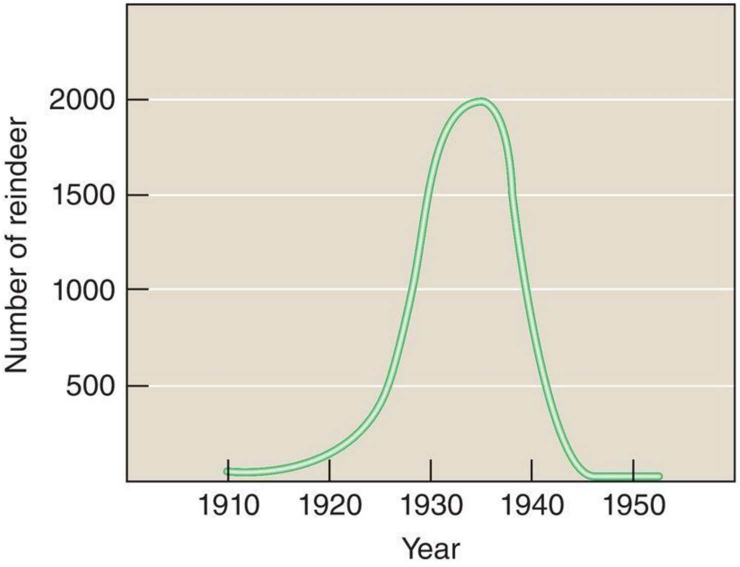
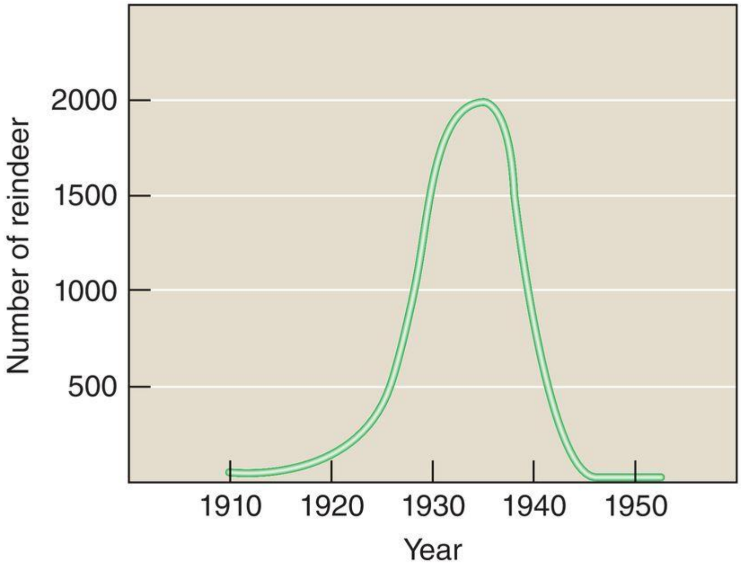


Factors That Affect Population Size

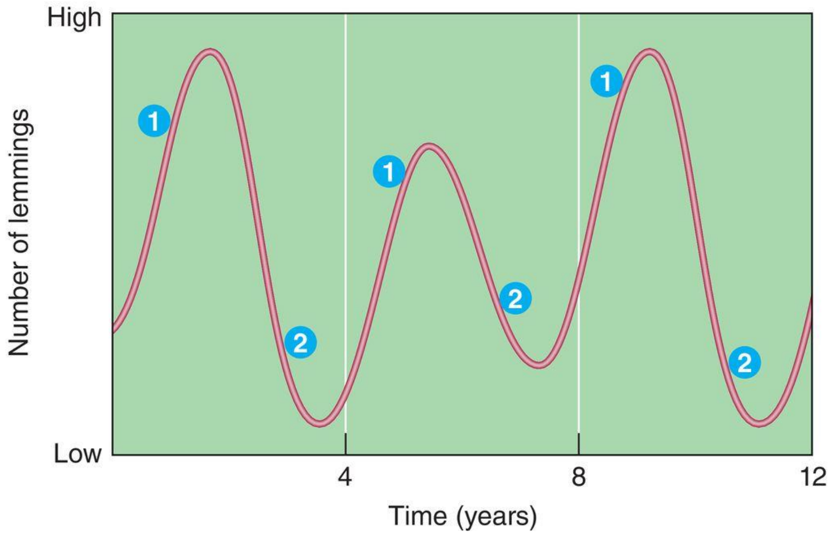
- Density Dependent Factor
  - Factor whose effect on population changes as population density changes
  - Examples:
    - Predation
    - Disease
    - Competition
  - Sometimes cause Boom-or-Bust Population Cycles



Boom-Or-Bust Population Cycles

Tom McHugh/Science Source

- Oscillations in population level can be difficult to predict or manage



Factors That Affect Population Size

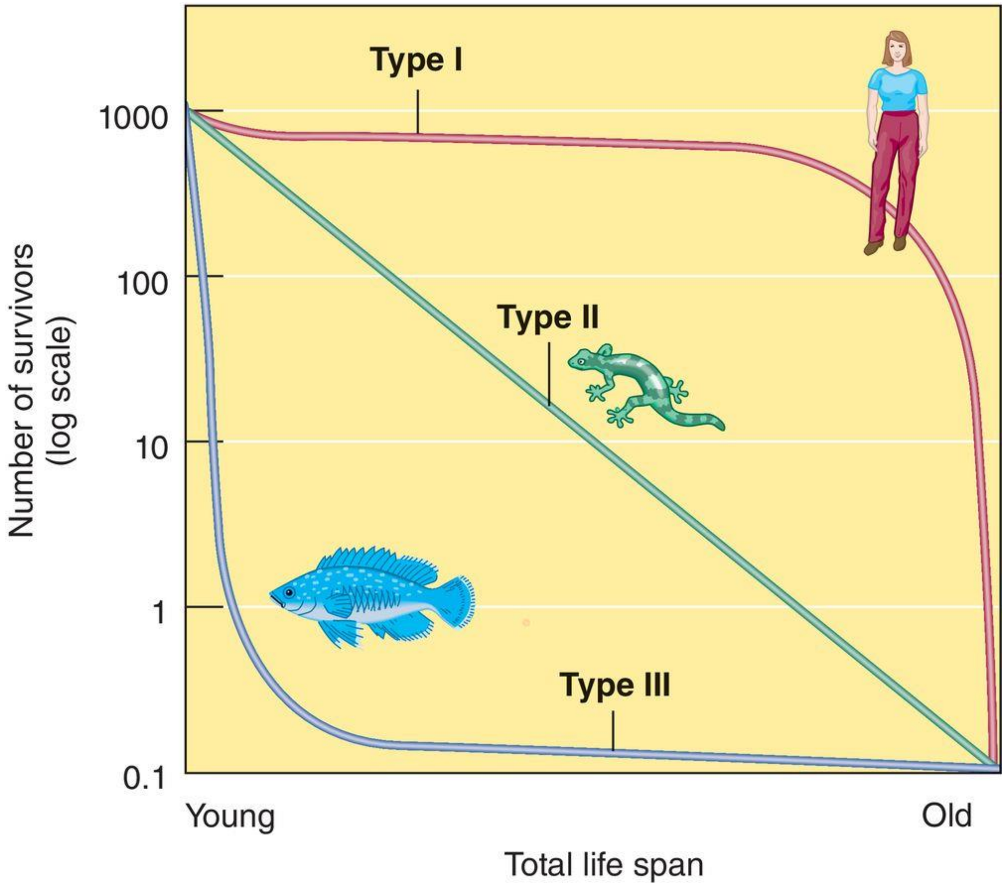
- Density Independent Factors
  - Factors that affects population size, but is not influenced by changes in population density
  - Examples:
    - Killing frost
    - Severe blizzard
    - Fire

Reproductive Strategies

r-selected species	*K*-selected species
- Small body size - Early maturity - Short life span - Large broods - Little or no parental care - Probability of long term survival is low - Mosquitoes and Dandelions	- Small broods - Long life span - Slow development - Large body size - Late reproduction - Low reproductive rate - Redwood trees and human beings

Survivorship

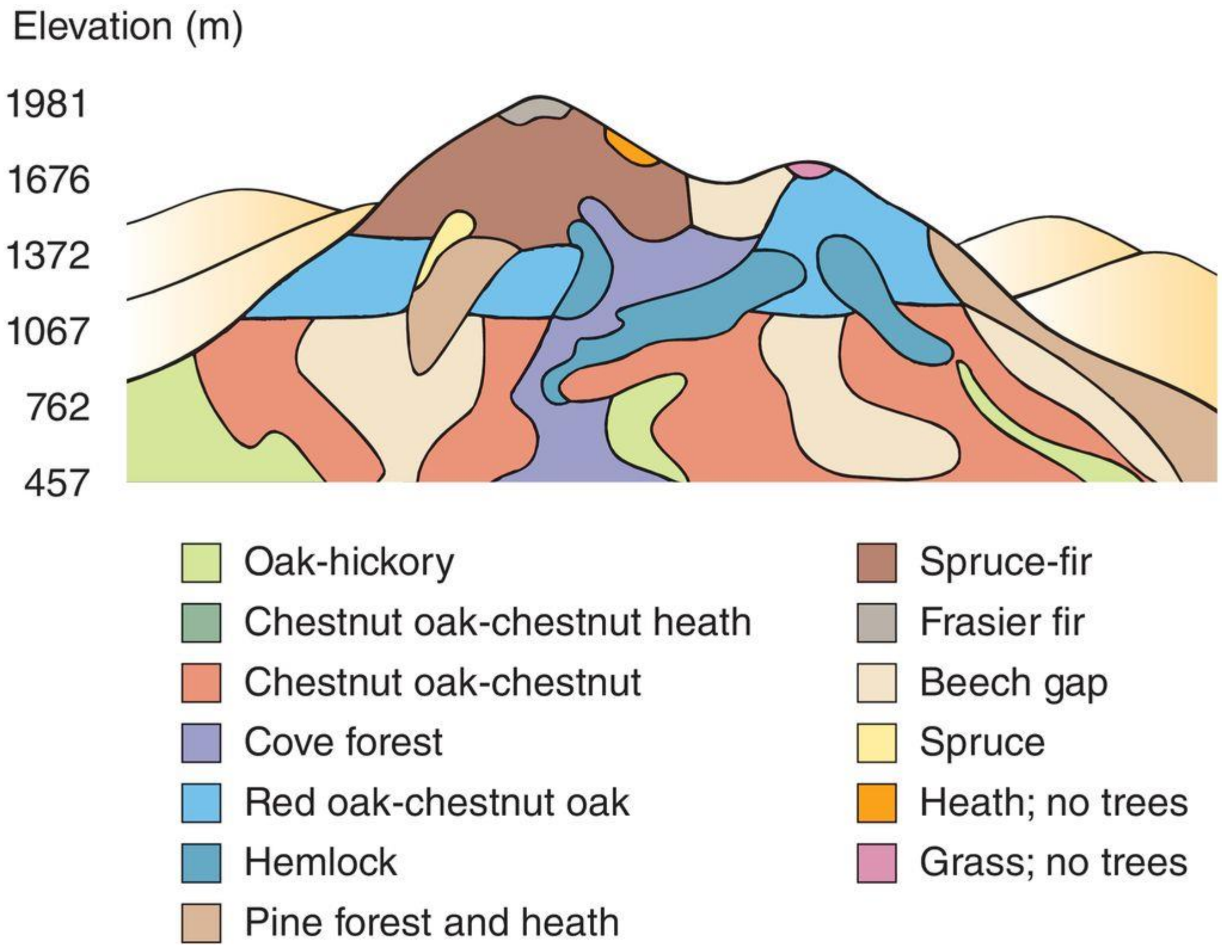
- Survivorship
  - Proportion of individuals surviving at each age in population
  - Formed from life tables



Metapopulations

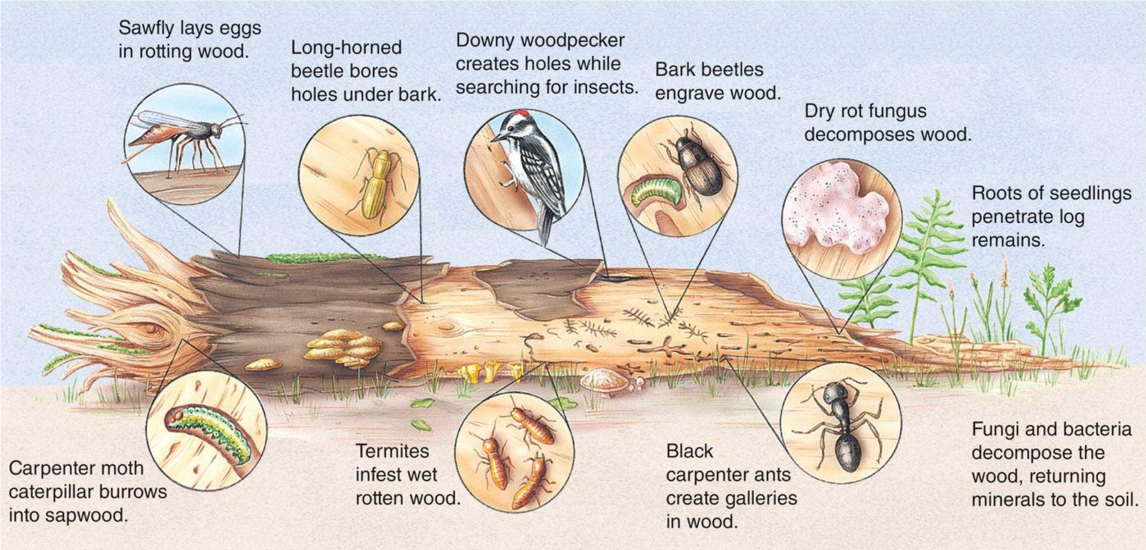
- A set of local populations among which individuals are distributed in distinct habitat patches across a landscape
- Source habitats
  - More suitable, births > deaths
  - high emigration (dispersal)
- Sink habitats
  - Less suitable habitat, births < deaths
  - Immigration needed to maintain population

Metapopulations



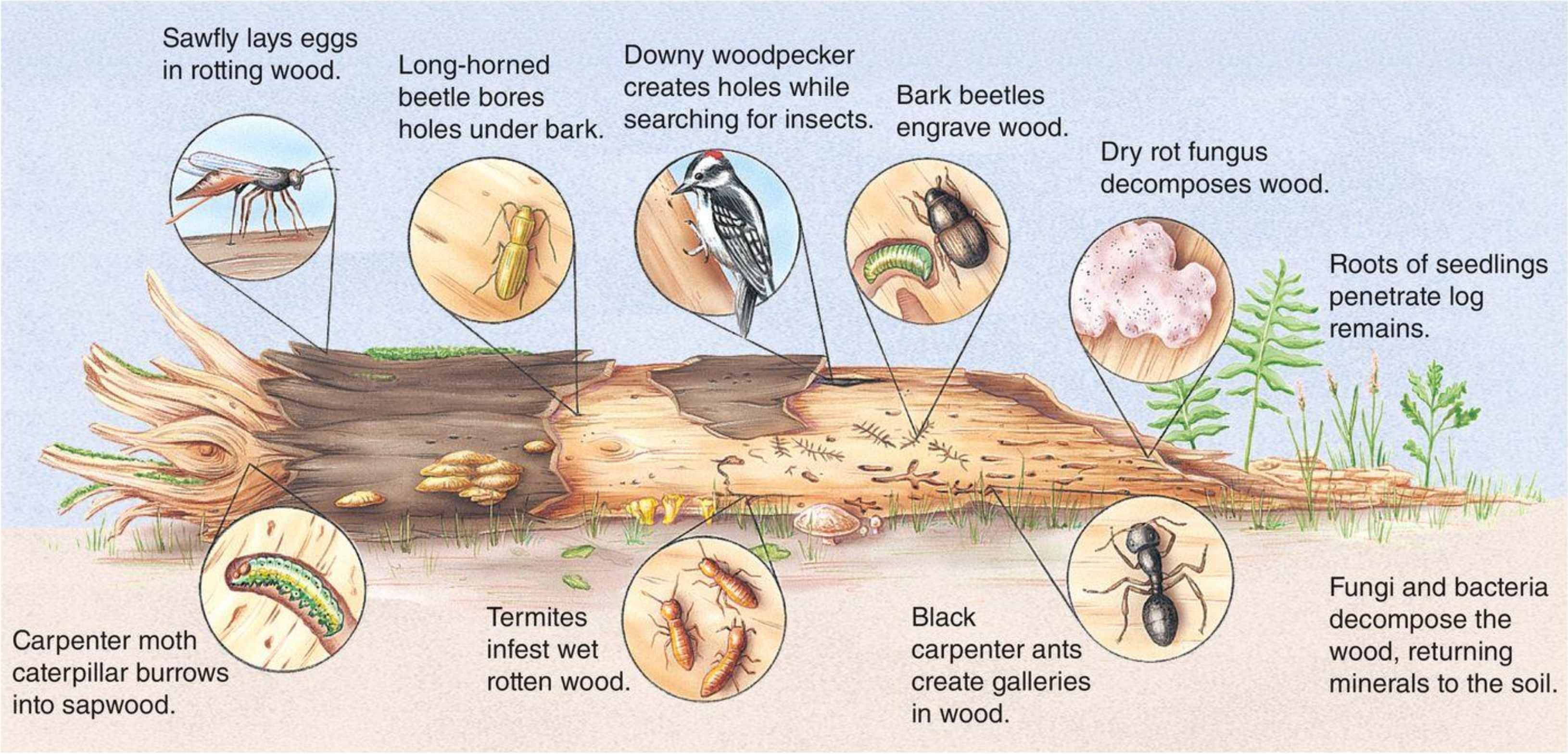
Biological Communities

- Association of different populations of organisms that live and interact in same place at same time
- Communities vary greatly in size and lack precise boundaries



Biological Communities

- When include non-living environment, termed ecosystem



Ecological Niche

- Niche is an organism's role
  - The totality of an organism's adaptations, its use of resources, and the lifestyle to which it is fitted
- Takes into account all aspect of an organism's existence
  - Physical, chemical, biological factors needed to survive
  - Habitat
  - Abiotic components of the environment

Ecological Niche

- Fundamental niche
  - Potential idealized ecological niche
- Realized niche
  - The actual niche the organism occupies
- Ex: Green Anole and Brown Anole

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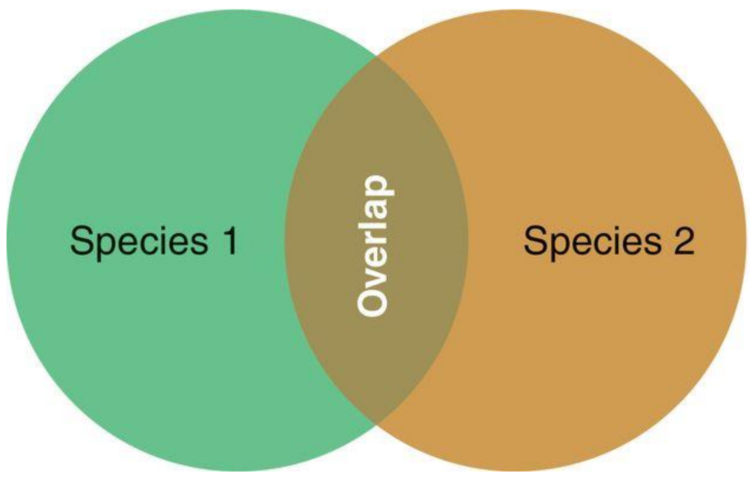
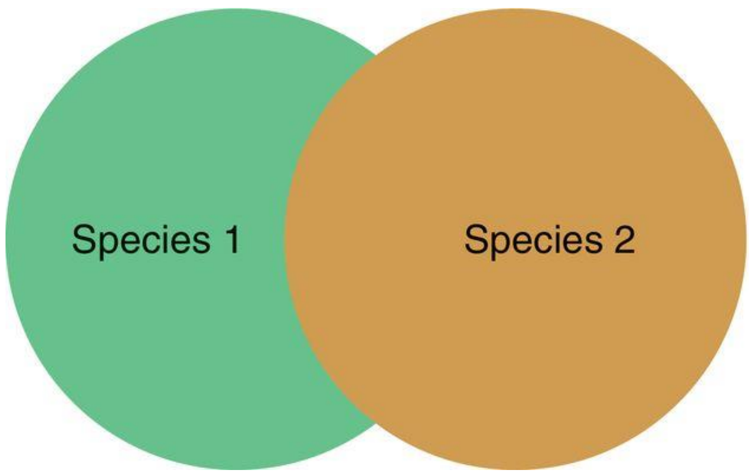
Ecological Niche

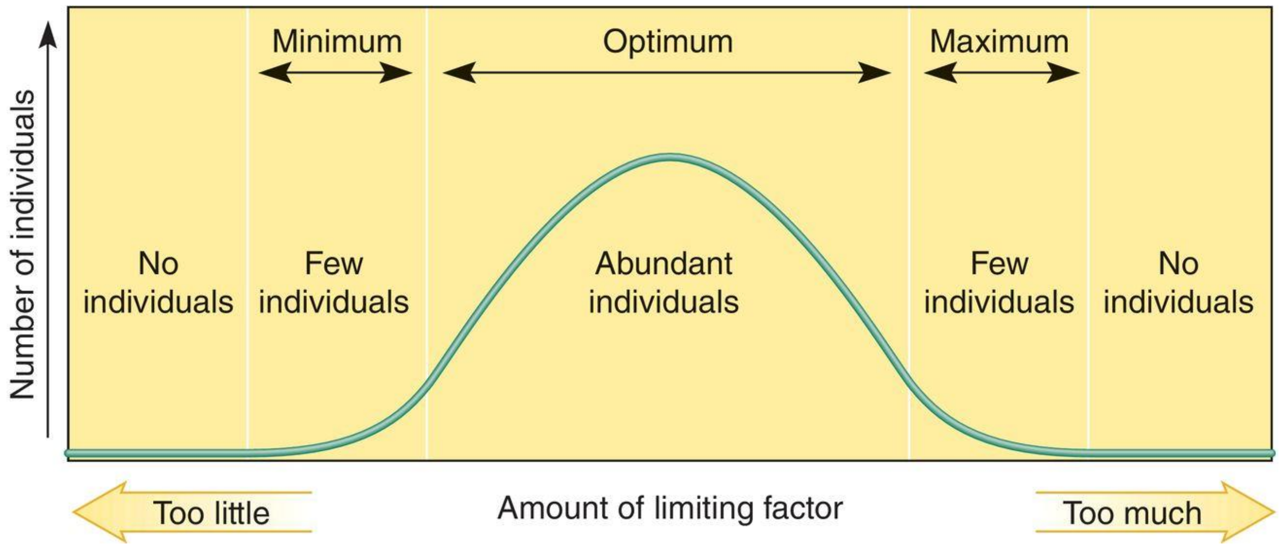
- Green Anole and Brown Anole
  - Fundamental niches of 2 lizards initially overlapped
  - Brown anole eventually out-competed the green anole for resources
  - Drove out green anole, thereby reducing the green anole's realized niche





Limiting Resources

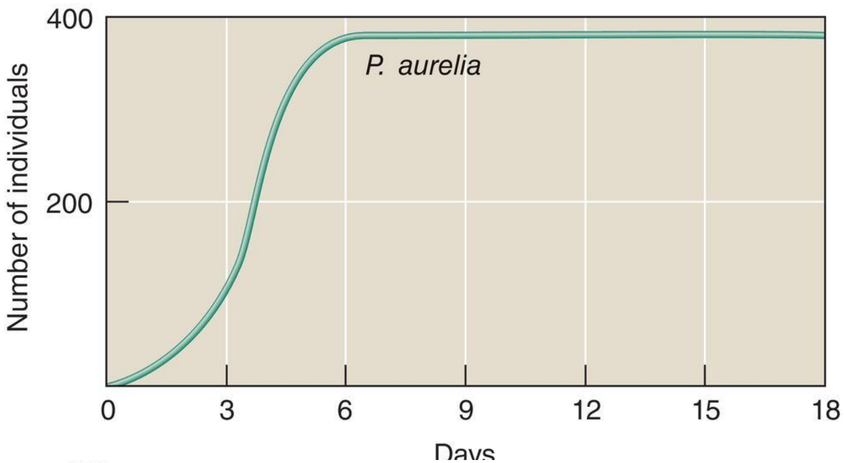
- Any environmental resource that, because it is scarce or at unfavorable levels, restricts the ecological niche of an organism
  - Ex: nutrients, food, territory, water
- Organisms compete when resources are not plentiful



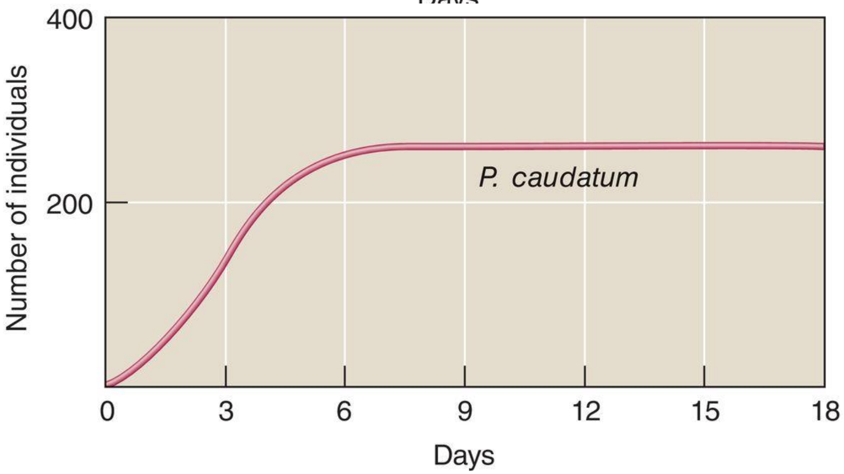
Competition

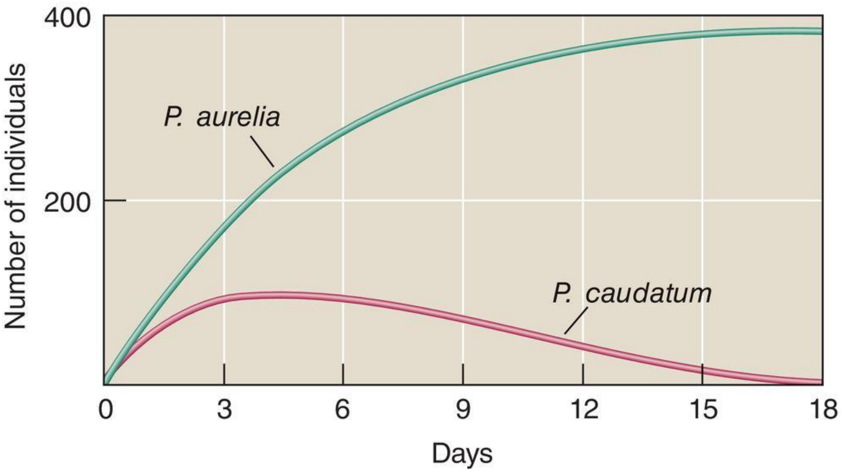
- Interaction among organisms that vie for the same resource in an ecosystem
- Intraspecific
  - Competition between individuals in a population
- Interspecific
  - Competition between individuals in 2 different species

Interspecific Competition



- Species have different K values
- When grown together, *P. aurelia* outcompetes





Competitive Exclusion & Resource Petitioning

- Competitive Exclusion
  - One species excludes another from a portion of the same niche as a result of competition for resources
- Resource Partitioning (below)
  - Coexisting species' niche differ from each other

Symbiosis

- An intimate relationship between members of 2 or more species
  - Participants may be benefited, harmed or unaffected by the relationship
  - Result of coevolution
- Three types of symbiosis
  - Mutualism
  - Commensalism
  - Parasitism

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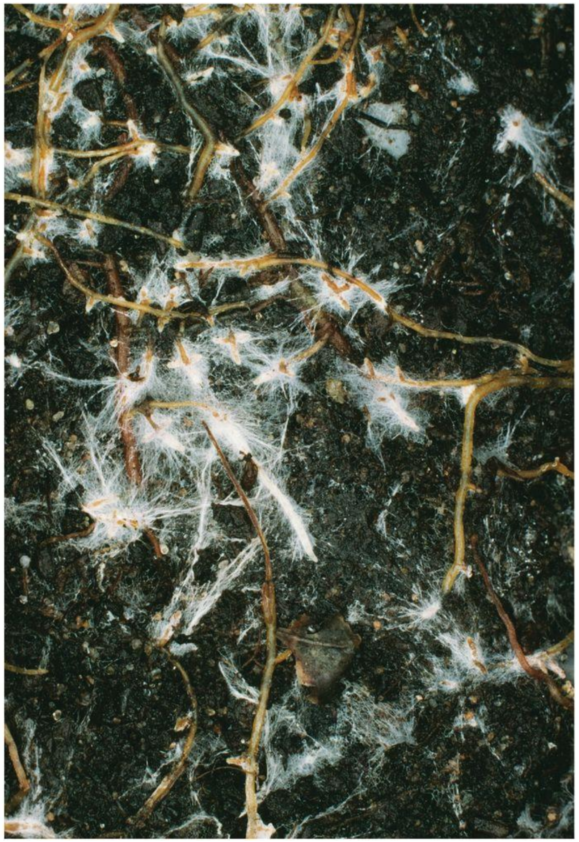
Mutualism

- Symbiotic relationship in which both members benefit
- Examples
  - Mycorrhizal fungi and plant roots
    - Fungus provides roots with unavailable nitrogen from soil
    - Roots provide fungi with energy produced by photosynthesis in the plant
  - Zooxanthellae and marine coral
    - Work similarly



Dr. Jeremy Burgess / Science Source

Commensalism

- Symbiotic relationship where one species benefits and the other is neither harmed nor helped
- Ex: epiphytes and tropical trees
  - Epiphytes use tree as anchor
  - Epiphyte benefits being closer to sunlight, tree is not affected

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Parasitism

- Symbiotic relationship in which one species is benefited and the other is harmed
  - Parasites rarely kill their hosts
- Ex: ticks
  - Ticks attach themselves to skin of animals and consume their blood

Laszlo Podor Photography / Getty Images

Predation

- The consumption of one species by another
- Many predator-prey interactions
  - Most common is pursuit and ambush (hunting)
- Plants and animals have established specific defenses against predation through evolution

Pursuit and Ambush

- Pursuing prey - chasing prey down and catching it
  - Ex: Day gecko and spider; orcas (killer whales) and salmon
- Ambush - predators catch prey unaware
  - Camouflage
  - Attract prey with colors or light

Plant Defenses Against Herbivores

- Plants cannot flee predators
- Adaptations
  - Spikes, thorns, leathery leaves, thick wax
  - Protective chemicals that are poisonous or unpalatable
  - Examples: active chemicals in tobacco, opium poppy, marijuana, peyote
    - Milkweeds produce cardiac glycosides and deadly alkaloids

Defensive Adaptation of Animals

- Fleeing or running
- Mechanical defenses
  - Ex: quills of porcupines, shell of turtles
- Living in groups
- Warning coloration
  - Bright colors that prompt avoidance
  - Chemical defenses- poisons
    - Ex: brightly colored poison arrow frog; milkweed moth caterpillar

Defensive Adaptation of Animals

- Cryptic coloration
  - Animals blend into surroundings
  - Helps animals hide from predators
  - Example: pygmy sea horse on gorgonian coral


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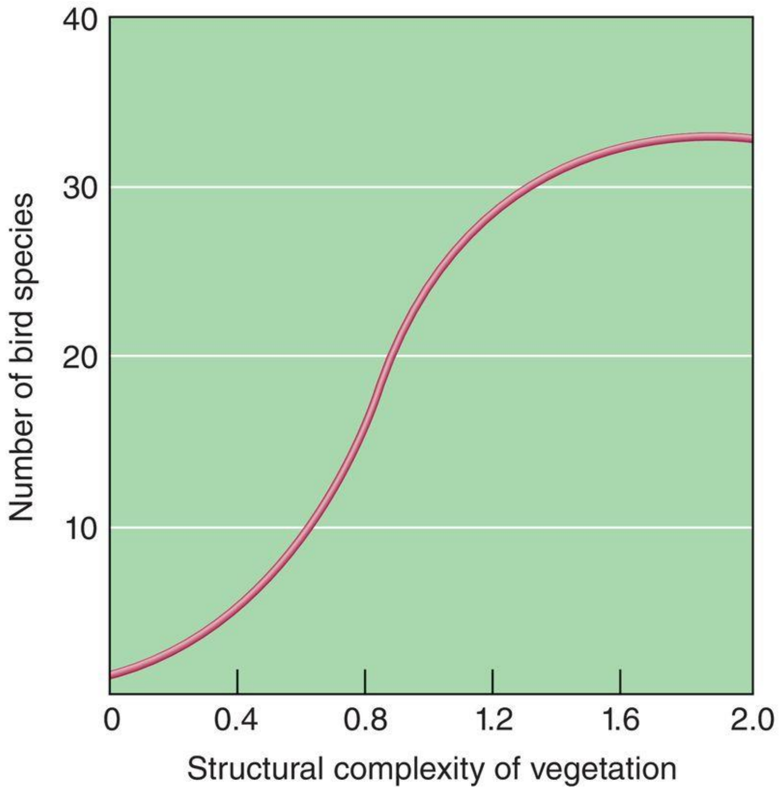
Keystone Species

- A species, often a predator, that exerts profound influence on a community
  - More important to the community than what would be expected based on abundance
- The dependence of other species on the keystone species is apparent when the keystone species is removed
  - Protecting keystone species is a goal to conservation biologists
- Examples: Yellowstone wolf, beaver

Species Richness

- The number of species in a community
  - Tropical rainforests = high species richness
  - Isolated island = low species richness
- Related to the abundance of potential ecological niches
- Richness often greater at margins due to transition - ecotone



Ecosystem Services

- Important environmental benefits that ecosystems provide, such as:
  - Clean air to breathe
  - Clean water to drink
  - Fertile soil in which to grow crops

Table 5.1 Ecosystem Services

Ecosystem	*Services Provided by Ecosystem*
Forests	• Purify air and water • Produce and maintain soil • Absorb carbon dioxide (carbon storage) • Provide wildlife habitat • Provide humans with wood and recreation
Freshwater systems (rivers and streams, lakes, and ground-water)	• Moderate water flow and mitigate floods • Dilute and remove pollutants • Provide wildlife habitat • Provide humans with drinking and irrigation water • Provide transportation corridors • Generate electricity • Offer recreation
Grasslands	• Purify air and water • Produce and maintain soil • Absorb carbon dioxide (carbon storage) • Provide wildlife habitat • Provide humans with livestock and recreation
Coasts	• Provide a buffer against storms • Dilute and remove pollutants • Provide wildlife habitat, including food and shelter for young marine species • Provide humans with food, harbors, transportation routes, and recreation
Sustainable agricultural ecosystems	• Produce and maintain soil • Absorb carbon dioxide (carbon storage) • Provide wildlife habitat for birds, insect pollinators, and soil organisms • Provide humans with food and fiber crops

Adapted from p. 527 of *Climate Change Impacts in the United States,* a report of the National Assessment Synthesis Team, U.S. Global Change Research Program, Cambridge University Press [2001].

Community Stability

- Absence of change in make up of a community
- Result of:
  - Resistance- ability to withstand disturbance
  - Resilience – ability to recover quickly to former state after disturbance
- Research has indicated that species richness can make communities more stable
  - Example: organic farmers and wide array of produce

Gardens as Ecosystems

- Gardens can support people and wildlife
- Spaces between crops are perfect for r selective species (weeds)
  - Plant others to outcompete weeds
- Crops that support predators of pests; build soil for continual harvest
- Rely on mutualisms

Community Development

- Ecological succession: the process where a community develops slowly through a series of species
  - Earlier species alter the environment in some way to make it more habitable by other species
  - As more species arrive, the earlier species are outcompeted and replaced
- Two types of succession
  - Primary succession
  - Secondary succession

Primary Succession

- Succession that begins in a previously uninhabited environment
  - No soil is present
  - Ex: bare rocks, cooled lava fields, sand dunes etc.
- General Succession Pattern
  - Lichen secrete acids that crumble the rock (soil begins to form)

Lichen → mosses → grasses → shrubs → forests

1

2

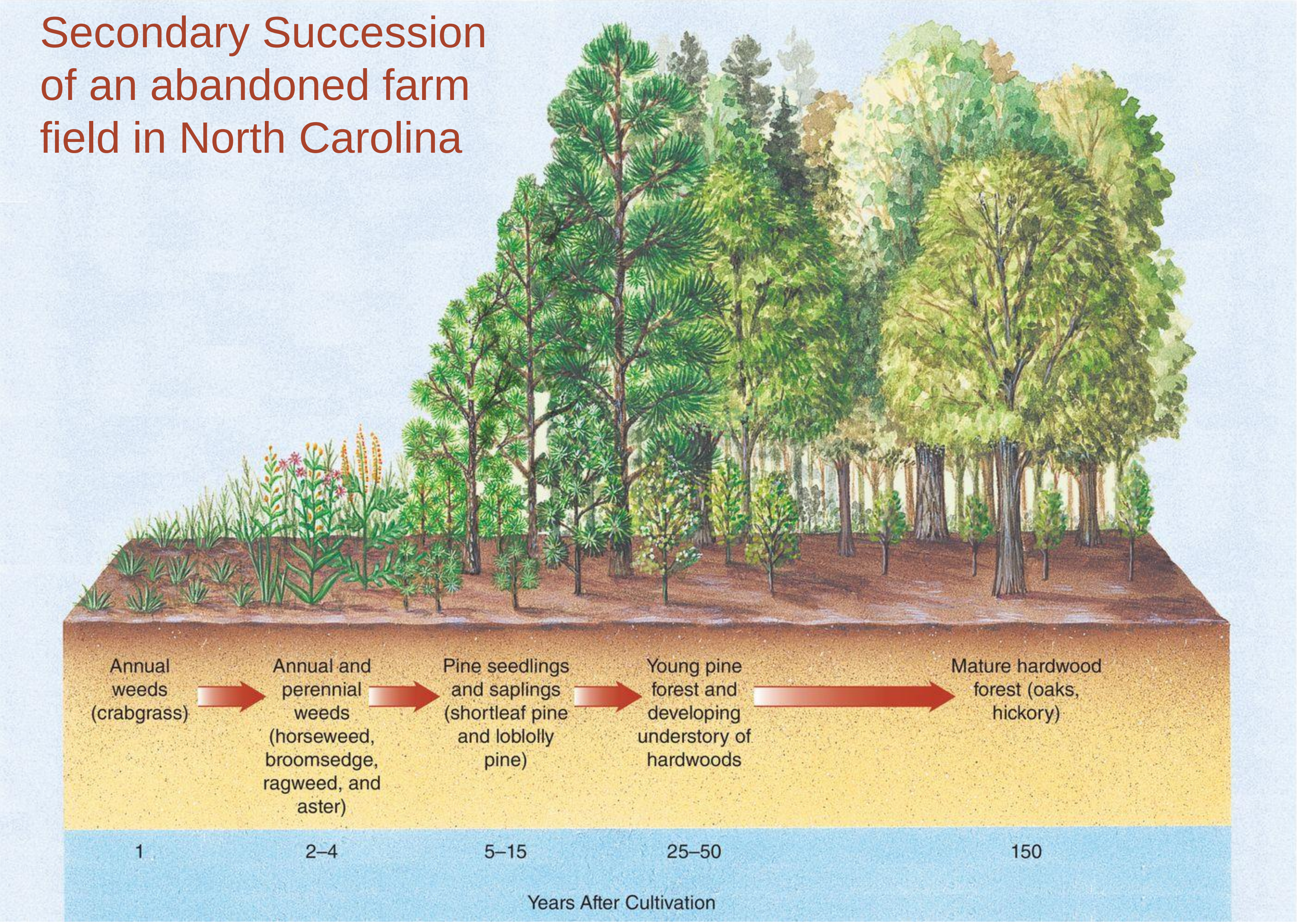
3

- Primary Succession
  1. Barren landscape rock with lichen & small shrubs
  2. Dwarf trees & shrubs
  3. Spruces dominate

Secondary Succession

- Succession that begins in an environment following destruction of all or part of the earlier community
  - Ex: abandoned farmland, open area after fire
- Generally occurs more rapidly than primary succession

Secondary Succession of an abandoned farm field in North Carolina



ENVIRONEWS

- Huge die-off of honeybee colonies (2006)
  - Used for pollination of ~90 commercial crops
- Colony collapse disorder (CCD)
  - Bees mysteriously left colonies
  - No dead bees for autopsies
- Link with two parasites –fungus and virus (2010 research)
  - Both needed for collapse, one causes sickness
- Pesticides suspected of weakening bees making them more susceptible to parasites