ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 5

Evolution, Biodiversity, and Population Ecology

Part 1: Foundations of Environmental Science

PowerPoint® Slides prepared by
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Striking gold in Costa Rica

- Golden toads were discovered in 1964, in Monteverde, Costa Rica
- The mountainous cloud forest has a perfect climate for amphibians
- Unfortunately, they became extinct within 25 years
  - Due to global warming's drying effect on the forest

Evolution: the source of Earth's biodiversity

- **Biological evolution** = genetic change in populations of organisms across generations
- May be random or directed by natural selection
  - **Natural Selection** = the process by which traits that enhance survival and reproduction are passed on more frequently to future generations than those that do not

(a) Resplendent quetzal

(c) Harlequin frog

(d) Scutellerid bug

(b) Puffball mushroom

Understanding evolution is vital

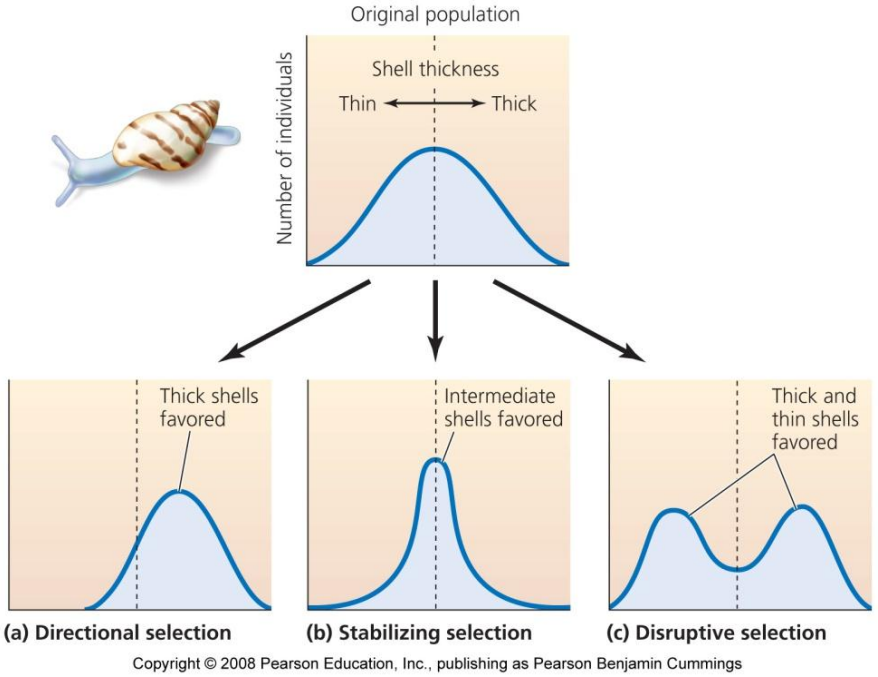
- It alters the genetic makeup of a population
- It is important for understanding antibiotic and pesticide resistance, agricultural issues, production, medicines, etc.
- Organisms adapt to their environment and change over time

Genetic variation

- **Adaptive Trait (Adaptation)** = a trait that promotes reproductive success
- **Mutations** = accidental changes in DNA that may be passed on to the next generation
  - Non-lethal mutations provide the genetic variation on which natural selection acts
- Sexual reproduction also leads to variation

Natural selection acts on genetic variation

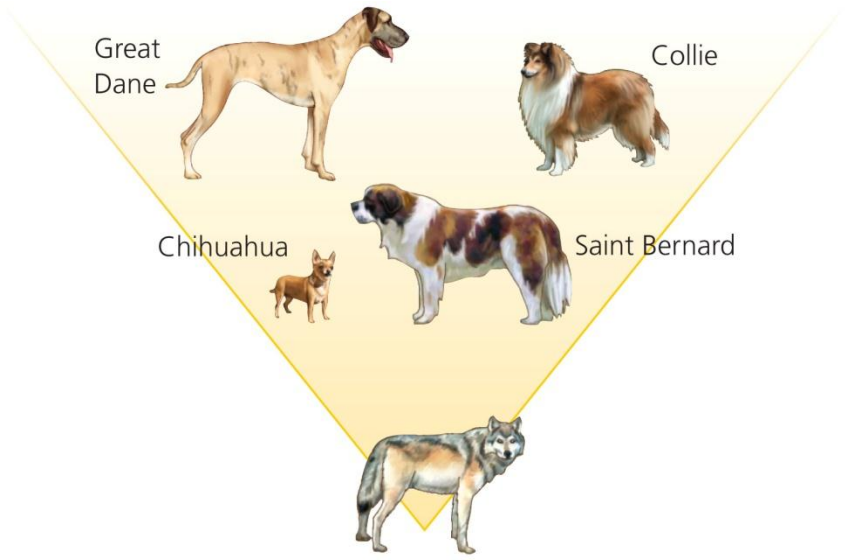
- **Directional selection** = drives a feature in one direction
- **Stabilizing selection** = produces intermediate traits, preserving the status quo
- **Disruptive selection** = traits diverge in two or more directions



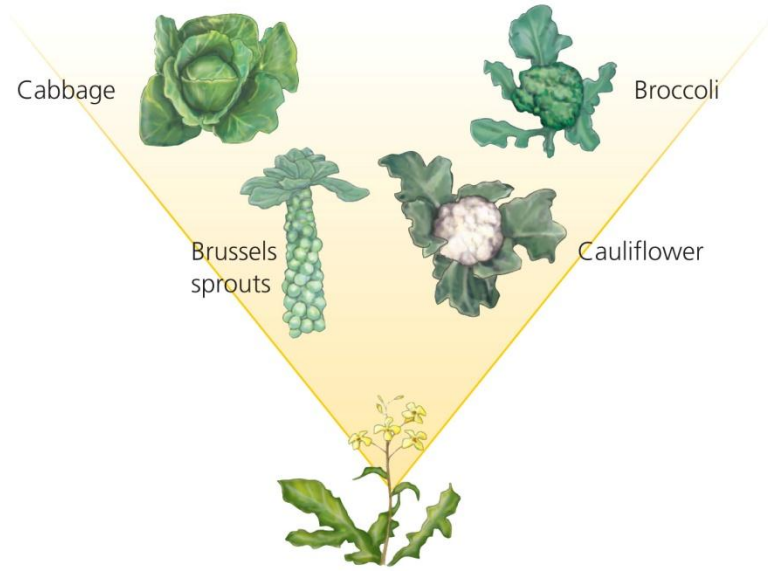
If the environment changes, a trait may no longer be adaptive

Artificial selection

- **Artificial Selection** = the process of selection conducted under human direction
  - For example, artificial selection has led to the great variety of dog breeds



(a) Ancestral wolf and derived dog breeds



(b) Ancestral *Brassica oleracea* and derived crops

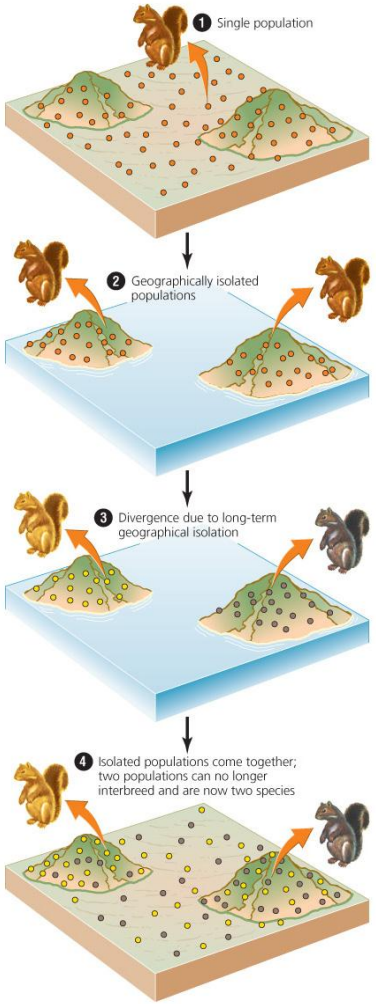
Evolution generates biodiversity

- **Biological Diversity** = An area's sum total of all organisms
  - The diversity of species
  - Their genes
  - Their populations
  - Their communities

- **Species** = a population or group of populations whose members share characteristics and can freely breed with one another and produce fertile offspring
- **Population** = a group of individuals of a species that live in the same area

Speciation produces new types of organisms

- The process of generating new species
  - A single species can generate multiple species
- **Allopatric speciation** = species formation due to physical separation of populations
  - Can be separated by glaciers, rivers, mountains
  - The main mode of species creation

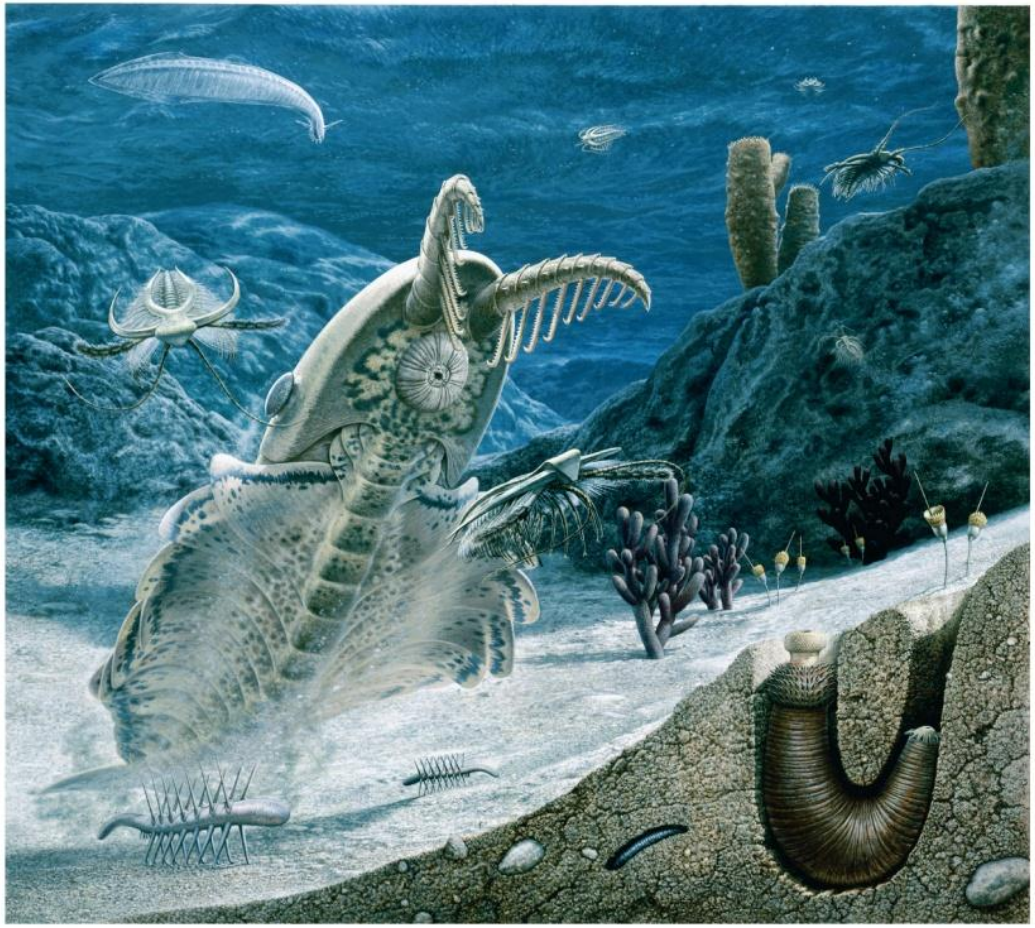


Another type of speciation

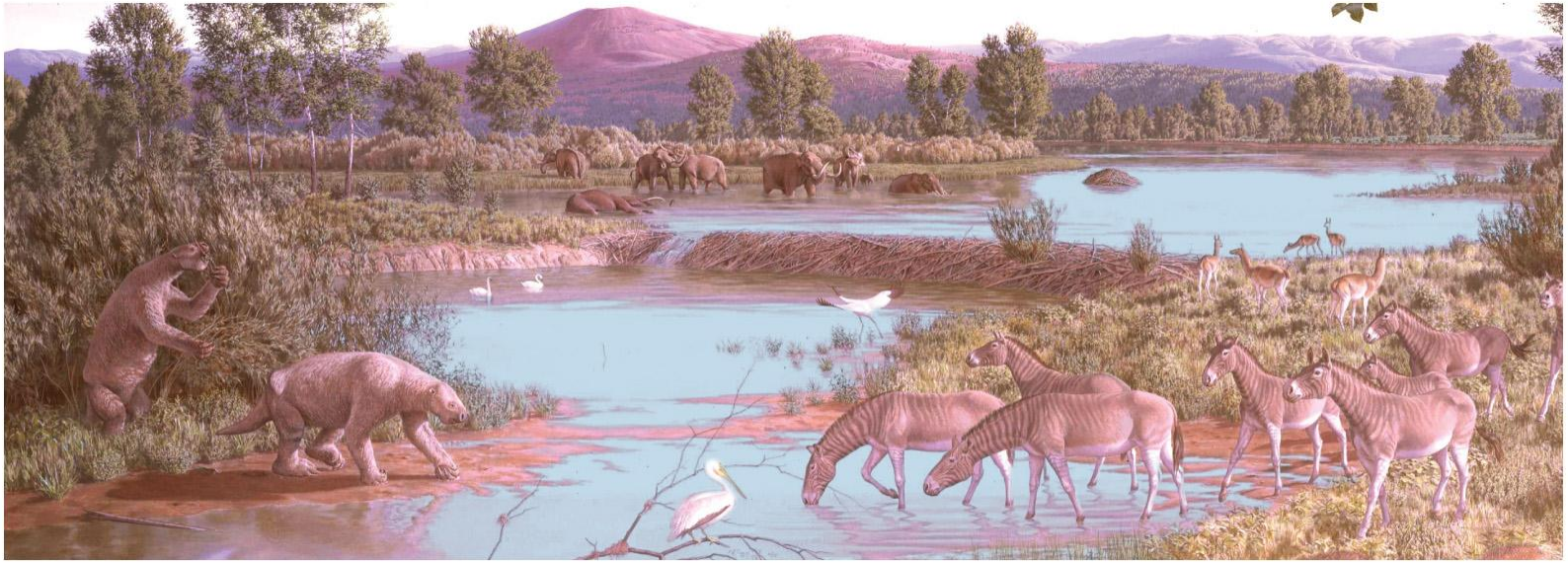
- **Sympatric speciation** = species form from populations that become reproductively isolated within the same area
  - Feed in different areas, mate in different seasons
  - Hybridization between two species
  - Mutations

Extinction

- Species generally evolve from simple to complex and small to big, but the opposite can occur, and some even disappear
- **Extinction =** the disappearance of a species from Earth
  - *Occurs when a species cannot adapt quickly enough to a changing environment*
  - Speciation and extinction affect species numbers



Extinction is a natural process



- Extinction is irreversible: once a species is lost, it is lost forever
- Humans profoundly affect *rates* of extinction

Some species are more vulnerable to extinction

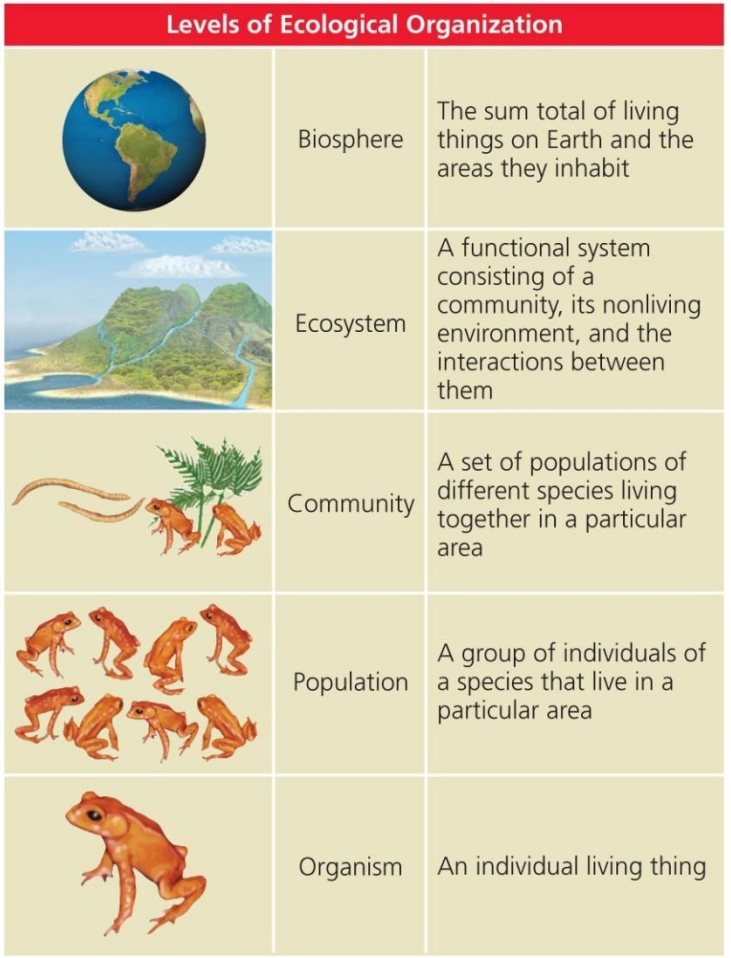
- Extinction occurs when the environment changes too rapidly for natural selection to keep up
- **Endemic species** = a species only exists in a certain, specialized area
  - Very susceptible to extinction
  - These species usually have small populations
- Many other factors also cause extinction
  - Severe weather
  - New species
  - Specialized species

Earth has had several mass extinctions

- **Background extinction rate** = extinction usually occurs one species at a time
- **Mass extinction events** = five events in Earth's history that killed off massive numbers of species at once
  - 50-95% of all species went extinct at one time
- Humans are causing the sixth mass extinction event
  - Resource depletion
  - Population growth
  - Development

Ecology is studied at several levels

- Ecology and evolution are tightly intertwined
- **Biosphere** = the total living things on Earth and the areas they inhabit
- **Ecosystem** = communities and the nonliving material and forces they interact with
- **Community** = interacting species that live in the same area



Organismal ecology: habitat

- **Habitat** = the environment in which an organism lives
  - Includes living and nonliving elements
  - Scale-dependent: from square meters to miles
- **Habitat use** = each organism thrives in certain habitats, but not in others
- **Habitat selection** = the process by which organisms actively select habitats in which to live
  - Availability and quality of habitat are crucial to an organism's well-being
  - Human developments conflict with this process

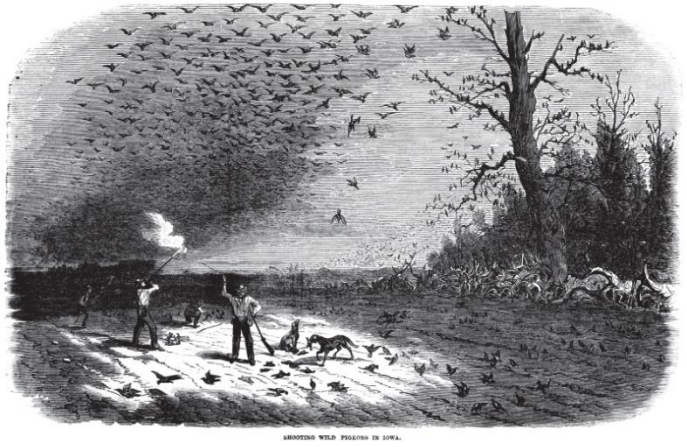
Organismal ecology: niche

- **Niche** = an organism's use of resources and its functional role in a community
  - Habitat use, food selection, role in energy and nutrient flow
  - Interactions with other individuals
- **Specialists** = species with narrow niches and very specific requirements
  - Extremely good at what they do, but vulnerable to change
- **Generalists** = species with broad niches that can use a wide array of habitats and resources
  - Able to live in many different places

Population characteristics

- All populations show characteristics that help scientists predict their future dynamics
- **Population size** = the number of individual organisms present at a given time
- **Population density** = the number of individuals within a population per unit area
  - High densities make it easier

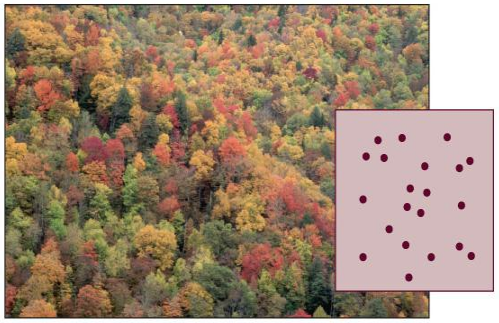
(a) Passenger pigeon



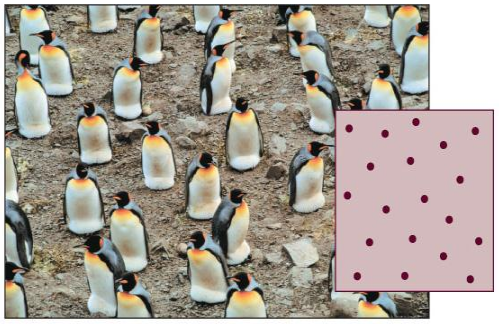
(b) 19th-century lithograph of pigeon hunting in Iowa

Population characteristics

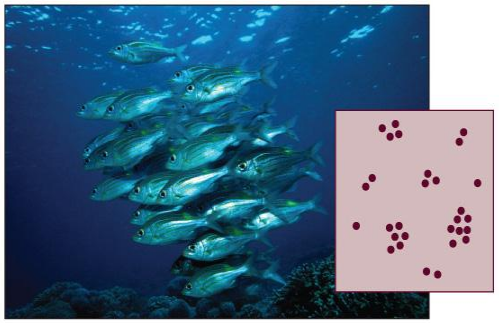
- **Population distribution (dispersion)** = spatial arrangement of organisms within an area
  - *Random* – haphazardly located individuals, with no pattern
  - *Uniform* – individuals are evenly spaced due to territoriality
  - *Clumped* – arranged according to availability of resources
    - Most common in nature



(a) Random



(b) Uniform



(c) Clumped

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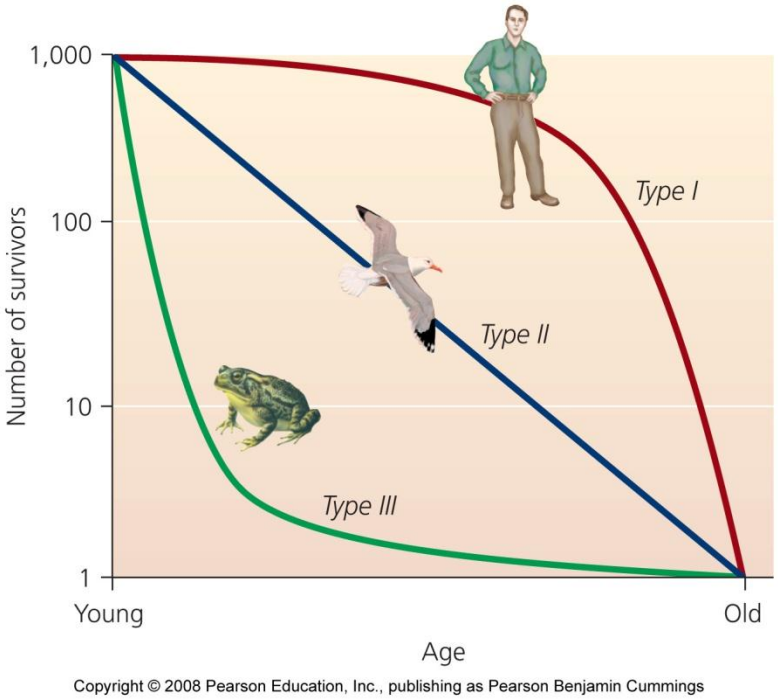
Birth and death rates

- **Crude birth/death rates** = rates per 1000 individuals
- **Survivorship curves** = the likelihood of death varies with age
  - Type I: More deaths at older ages
  - Type II: Equal number of deaths at all ages
  - Type III: More deaths at young ages

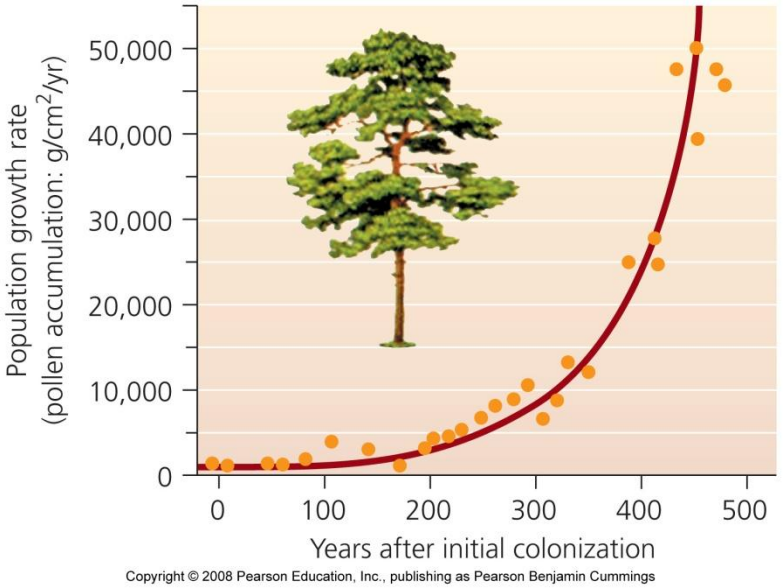


Four factors of population change

- **Natality** = births within the population
- **Mortality** = deaths within the population
- **Immigration** = arrival of individuals from outside the population
- **Emigration** = departure of individuals from the population
- Growth rate formula =
  - (Crude birth rate + immigration rate) - (Crude death rate + emigration rate) = Growth rate

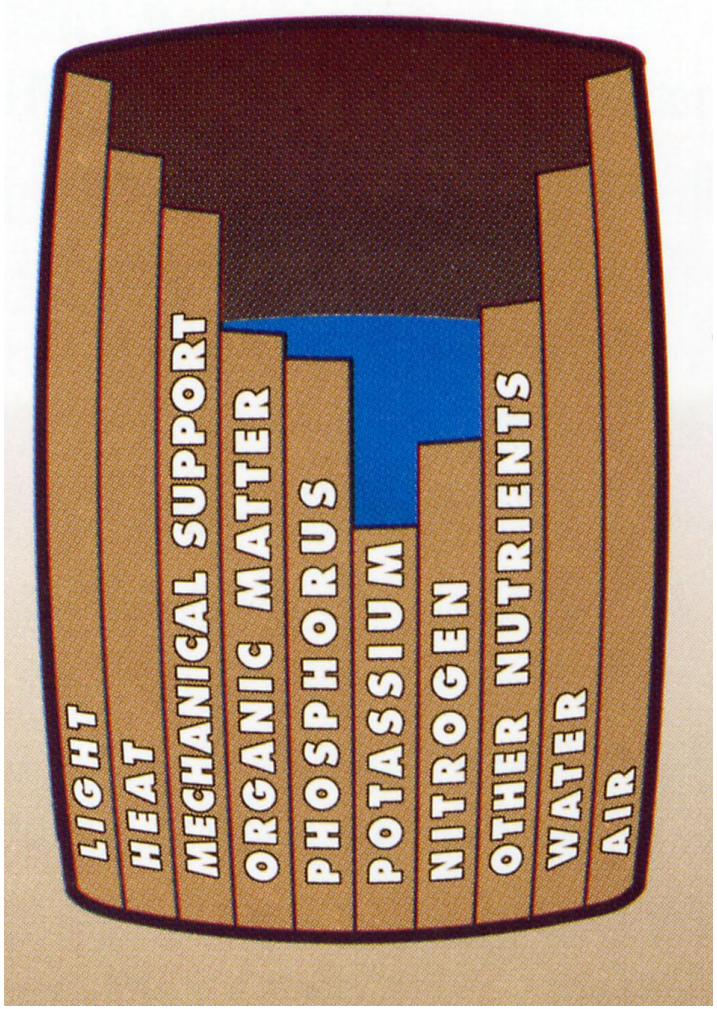
Exponential population growth

- *Steady* growth rates cause **exponential** population growth
  - Something increases by a fixed percent
  - Graphed as a J-shaped curve
- Exponential growth *cannot be sustained indefinitely*
  - It occurs in nature with a small population and ideal conditions

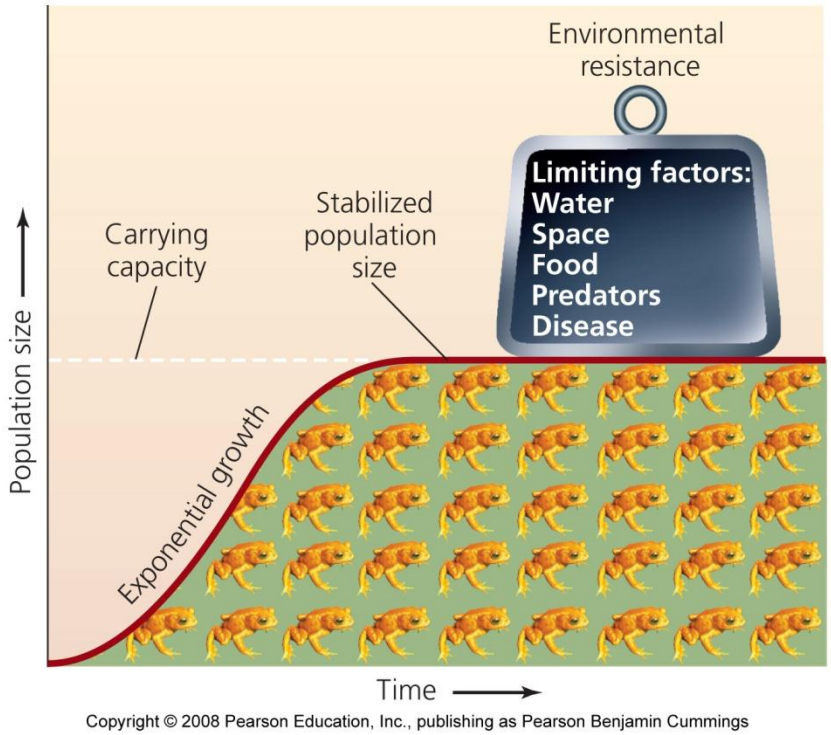


Limiting factors restrain growth

- **Limiting factors** = physical, chemical and biological characteristics that restrain population growth
  - Water, space, food, predators, and disease
- **Environmental resistance** = All limiting factors taken together



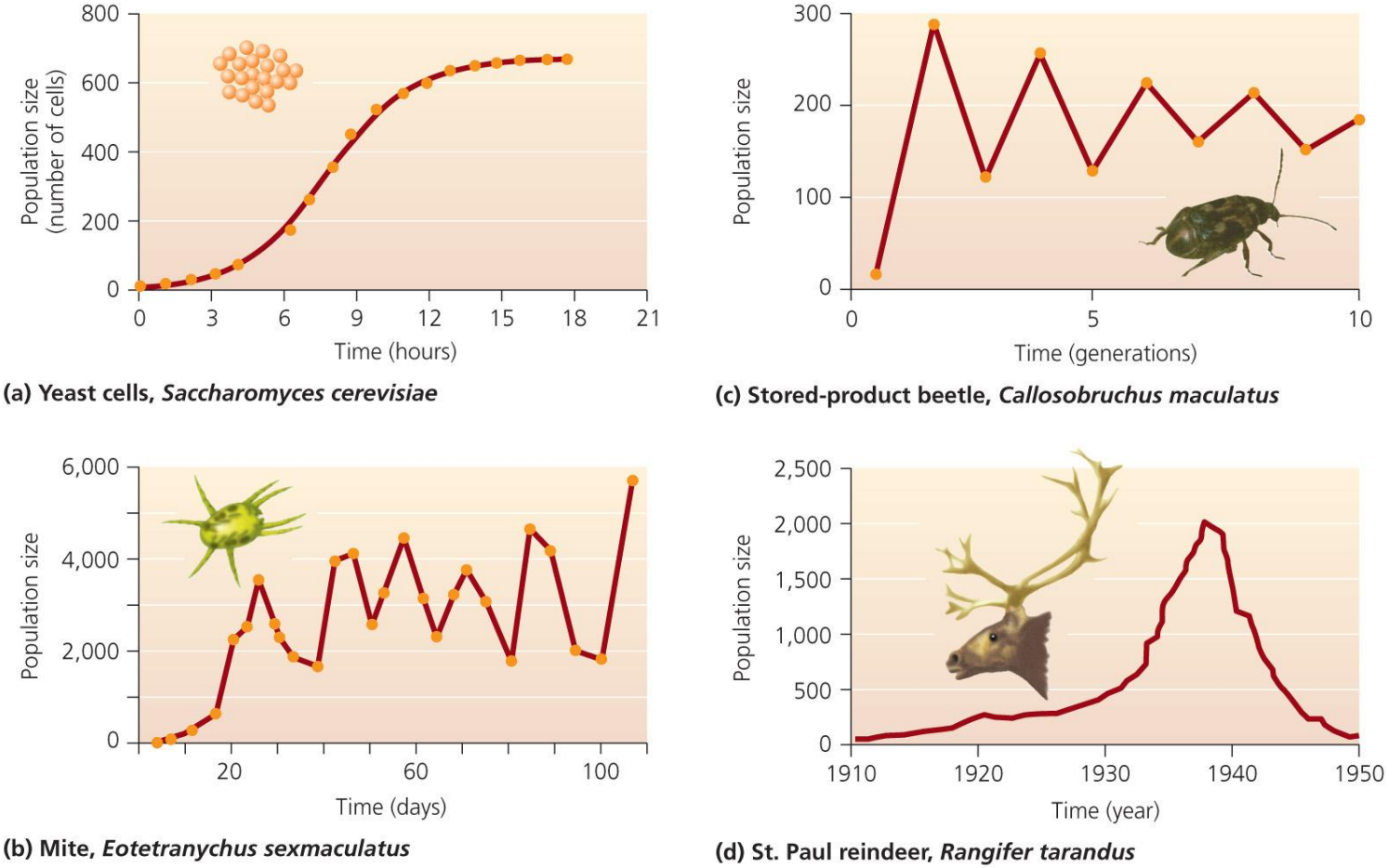
Carrying capacity



- **Carrying capacity** = the maximum population size of a species that its environment can sustain
  - An S-shaped **logistic growth curve**
  - Limiting factors slow and stop exponential growth
- Carrying capacity changes

Humans have raised their carrying capacity by decreasing the carrying capacity for other species

Perfect logistic curves aren't often found



Population density affects limiting factors

- **Density-dependent factors** = limiting factors whose influence is affected by population density
  - Increased risk of predation and competition for mates occurs with increased density
- **Density-independent factors** = limiting factors whose influence is not affected by population density
  - Events such as floods, fires, and landslides

Biotic potential and reproductive strategies vary

- **Biotic potential** = the ability of an organism to produce offspring
- **K-selected species** = animals with long gestation periods and few offspring
  - Have a *low* biotic potential
  - Stabilize at or near carrying capacity
  - Good competitors
- **r-selected species** = animals which reproduce quickly
  - Have a *high* biotic potential
  - Little parental care

K-selected vs. r-selected species

TABLE 5.4 Traits of r-selected and K-selected species

r-selected species	K-selected species
Small size	Large size
Fast development	Slow development
Short-lived	Long-lived
Reproduction early in life	Reproduction later in life
Many small offspring	Few large offspring
Fast population growth rate	Slow population growth rate
No parental care	Parental care
Weak competitive ability	Strong competitive ability
Variable population size, often well below carrying capacity	Constant population size, close to carrying capacity
Variable and unpredictable mortality	More constant and mortality predictable